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CONTENTS

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SYMPOSIUM ON CHLORINATION

Equipment for the Chlorination of Small Water Supplies. By Charles R. Cox 1587
Handling Chlorine to Avoid Trouble. By L. L. Hedgepeth 1602
Discussion of Papers on the Mechanics of Chlorination. By Charles E. Trowbridge 1621
A Review of the Status of the Ammonia Chlorine Process. By Marsden C. Smith 1623
The Efficiency of the Ammonia-Chlorine Process. By A. E. Griffin 1631
Chlorine and the Orthotolidine Test in the Presence of Nitrite. By Roberts Hulbert 1638
The Determination of Free Chlorine. By D. Tarvin, H. R. Todd and A. M. Buswell 1645
Discussion of Papers on Orthotolidine Test. By C. A. Holmquist 1663
Discussion of Papers Dealing with Chlorination. By Linn H. Enslow 1667

The Air Dilution Method of Odor Determination in Water Analysis. By Gordon M. Fair and William F. Wells 1670
The Occurrence and Control of Iron Bacteria in Water Bacteria. By K. W. Brown 1684
Report of Committee on Filtering Materials 1701
Coagulation with Iron Compounds. By A. P. Black 1713
Taste and Odor Control:
Introductory Statement. By John R. Baylis 1719
At Minneapolis, Minnesota. By Arthur F. Mellen 1720
At Saginaw, Michigan. By Alfred Eckert 1723
At Hackensack Water Company, New Jersey. By George R. Spalding 1730
Abstracts 1734

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• • • FAMOUS VICTIMS OF WATER BORNE DISEASES

LOST TO HIS COUNTRY . . . PRINCE ALBERT

*James A. Tobey, Dr P H
Water Works Eng Vol 87-7

BY his untiring efforts as Sponsor of the Great Exhibition of 1851; as President of the British Association for the Advancement of Science; as active patron of the Society of Arts, "Albert the Good", beloved Consort of Queen Victoria, did much to direct the application of science and invention to the betterment of the everyday life of his adopted countrymen

Had chlorination then been known, he would have been one of its most ardent advocates . . . and his own untimely death from typhoid fever—a water-borne disease—might well have been prevented. That the cost of chlorination —one cent per person per year—is so slight as to make it readily available to all, would have been to him one of its biggest appeals.

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84-W

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Discussion of all papers is invited

Vol. 26 NOVEMBER, 1934 No. 11

EQUIPMENT FOR THE CHLORINATION OF SMALL WATER SUPPLIES

By Charles R. Cox
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Most of the literature upon the chlorination of water is very general or deals with relatively large supplies where the practice has been quite highly standardized. Unfortunately, however, the problems of chlorinating small supplies are frequently the most difficult of solution. Because of this situation a study has been made of these problems.

There are 652 public water supplies in New York State with separate sources, 297 of which serve communities with populations less than 1,000. Although many of the smaller supplies are secured from wells or springs where frequently treatment is not needed, about 150, or one-half, of the small supplies are secured from impounding reservoirs where chlorination is provided or is desirable.

Small pumped supplies may be readily chlorinated through the use of manually controlled equipment, because of the uniform capacity of most pumps. Gravity supplies, however, present some unique problems due to the wide fluctuations in flow, the necessity of frequently selecting isolated locations for chlorination equipment to secure an adequate period of contact before the treated water reaches the consumers, or to secure a location where the water pressure is low enough to permit the direct application of chlorine gas or solution to the water supply. Such isolated locations complicate periodic super-

vision of the equipment, especially in winter, and hence chlorination equipment is frequently neglected. Furthermore, water stored in small reservoirs, or secured directly from small streams, fluctuates in quality to a larger extent than most large supplies, and hence the chlorine demand of the water varies to such a degree that control is complicated. Due to these factors it is essential that the chlorination equipment be carefully selected to meet local conditions, and to facilitate control.

METHODS OF CHLORINATION

Generally speaking, chlorination of small supplies may be accomplished in one of the following four ways:

1. Through the use of manually controlled, semi-automatic equipment for the application of liquid chlorine or hypochlorite solutions to pumped supplies.

2. Through the use of automatic equipment for the application of liquid chlorine or hypochlorite solutions to supplies flowing by gravity at varying rates.

3. Through the use of the chlorine-ammonia treatment of either pumped or gravity supplies. Equipment for this purpose may consist of apparatus for the application of chlorine and gaseous ammonia, or equipment for the application of hypochlorite solutions and solutions of ammonium sulphate or aqua-ammonia. The chlorine-ammonia treatment permits the use of manual control equipment to treat many gravity supplies where fluctuations in flow are not too great, because of the possibility of over-chlorinating the water without the production of taste. Recent experiences have shown, however, that chloramines may create a taste in smaller concentrations than originally expected, namely, 0.2 to 0.4 p.p.m. residual chlorine, so this treatment is not quite as flexible as anticipated. It is doubtful, therefore, whether this treatment can be used to insure adequate chlorination during periods of very heavy flow, such as occur during fires, and yet prevent chlorinous tastes during periods of minimum flow, unless the doses are regulated more frequently than usual, or automatic apparatus is utilized. In general, however, the chlorine-ammonia treatment is of great value, especially when tastes are likely to be troublesome and the secondary benefits of stable residual chlorine are desired.

4. Through the use of conventional chlorination followed by dechlorination. This method of treatment may be secured through the

use of typical chlorinators to apply a uniform dose in excess of the maximum requirements, and then through the addition of an "anti-chlor," such as ammonia gas, ammonium sulphate, aqueous-ammonia, sulphur dioxide, or sodium sulphite to remove the residual chlorine after a suitable contact or disinfecting period. Water may also be de-chlorinated by the use of activated carbon filters, provided the water is clear. This method of treatment is very satisfactory where chlorinated water must be delivered immediately to consumers, in which case very rapid disinfection is required and chlorinous taste must be avoided. It is possible, for instance, to chlorinate water entering a pump well and to de-chlorinate the water pumped into the distribution system, or to pump chlorinated water into a pressure reaction tank and then to de-chlorinate with activated carbon filters. Another procedure is to chlorinate a gravity supply at an impounding reservoir with a dose sufficient to meet the maximum demands and then de-chlorinate at some convenient point on the supply main between the reservoir and the distribution system. De-chlorination with ammonia will not prevent chloro-phenol tastes, unless the preliminary chlorine dose is sufficient to destroy the phenolic compounds, as in the case of superchlorination developed at Toronto. Ammonia is preferable as a de-chlorinating agent, however, because active disinfectants, the chloramines, are produced to continue disinfection into the distribution system, which is not the case with sulphur dioxide or sodium sulphite.

THE CONTROL OF AUTOMATIC CHLORINATORS

There has been a marked recent development of special apparatus for the application of hypochlorite solutions, or solutions of aqueous-ammonia or ammonium sulphate to water supplies. As some of this equipment may be automatically controlled, a brief consideration of available methods of control may be of interest.

Unfortunately master meters are not generally used in connection with small supplies, and hence their absence frequently discourages the use of automatic chlorinators when such are actually needed to secure satisfactory results. This necessity is readily made evident by considering the rate of flow of gravity supplies of small communities. First, there is the zone of minimum flow during the early morning hours, where leakage accounts for most of the consumption. Secondly, there is the zone of normal consumption, which has a peak about 9 to 10 A.M. Thirdly, there is a zone represented by

temporary and infrequent flow during periods of fire, where the total consumption in small villages may be ten times the average. Notwithstanding this situation, manually controlled chlorinators are frequently used with the assumption that the orthotolidine test will permit adequate adjustment of the dose. This is frequently impracticable, however, because of the limitations of periodic supervision.

Venturi meter tubes may be purchased without recording or indicating equipment at relatively small expense. Such meters permit the automatic control of gaseous chlorinators and also the automatic control of certain types of hypochlorite solution feeders. For instance, the differential head at the meter may be used to operate the displacement type of equipment, where a proportional flow of water, subject to control, would enter a pressure tank and displace an equal volume of hypochlorite solution. This equipment will function irrespective of the pressure on the pipe line and hence may be located where operation would be most convenient. Secondly, a small meter may be placed on a small pipe line connected to a Venturi meter, whereby the differential head would cause proportional flow through the small meter, which in turn would control certain types of automatic equipment feeding hypochlorite solutions. An orifice on the main pipe line may be utilized in place of venturi meters, but the total loss of head would be appreciably greater. A Pitot tube may also be inserted on the main line to operate displacement type of automatic chlorinators, although the small quantity of water passing through a Pitot tube could not be used to operate a small meter on a bypass line.

An entirely distinct method of automatic control of chlorinators of small supplies may be secured through the use of compound meters of the crest, turbine or propeller variety. This arrangement consists of a 4- to 8-inch main-line meter located at some convenient point, a 2-inch meter of the same type on a bypass around the main meter, and an automatic check valve on the main line, which would open when the loss of head through the bypass exceeds some desired value, such as 10 pounds. Two-inch crest or turbine meters have an accurate capacity range from about 5 to 150 gallons per minute, with a maximum loss of head of 10 pounds. Similar 4-inch meters have a range of about 30 to 450 gallons per minute, and a 6-inch meter about 70 to 1,000 gallons per minute, both maximum capacities being at a 10 pound maximum loss of head.

It is evident that this meter arrangement provides automatic con-

trol of certain types of hypochlorite solution feeders over the total range of gravity flow to small communities.

Still another available method of control of chlorination equipment is through the use of a small bypass meter around an automatic check valve similar to the arrangement referred to above, but where a large meter would not be utilized. A mercoid switch would be installed in its place to operate when the check valve opens during periods of heavy flow during fires, thereby starting a small motor to operate the same chlorinator, or a similar standby unit, at a predetermined rate, selected to meet the requirements of maximum demand. It is possible to reverse this arrangement and to use a large meter to provide automatic chlorination of the average and maximum flows, and to use a constant feed device to maintain a predetermined minimum rate of application of chlorine solution during periods when the flow is insufficient to operate the large meter.

DESCRIPTION OF COMMERCIAL CHLORINATORS

A very brief description of chlorination equipment available for the treatment of small supplies has been appended. In order that these data may be considered in connection with methods of control discussed above, it is desirable to classify the equipment into several distinct types.

First, there is the well known dry and solution feed chlorinators for the application of liquid chlorine, manufactured by the Filclor Company, The Pardee Engineering Company and the Wallace and Tiernan Company, Inc., which may be installed to start and stop automatically with pumps, but which otherwise would be subject to manual control. This type of equipment will function with doses as low as about $\frac{1}{4}$ pound of chlorine gas per day.

Secondly, there is the automatic equipment for applying gaseous chlorine, known as the Rotar type and Automatic Vacuum Chlorinator, manufactured by the Wallace & Tiernan Company, Inc., the first having a capacity from the lowest dose to about 5 pounds per day and the latter a capacity varying from about 1 pound to high values.

The application of gaseous chlorine rather than hypochlorite solutions by the first two types of equipment greatly simplifies control, because solutions do not need to be prepared.

Thirdly, there is the manual control equipment for the application of hypochlorite solutions, as manufactured by the Beaumont Apparatus Company, Hills-McCanna Co., Phipps and Bird, Inc., Omega

Machine Company, International Filter Company, Wallace & Tiernan Company, Inc., The Wilson Chlorinator and Sanitation Corporation, and the various companies manufacturing solution feed equipment utilizing orifice boxes, such as the conventional solution feed alum equipment.

The electrolytic cell of the Wallace & Tiernan Company, Inc., would be grouped with this manually controlled equipment.

The fourth type of equipment consists of automatic apparatus, which would be connected to the Venturi meters, orifices, Pitot tubes, where water displaces the hypochlorite solution stored in closed tanks at a rate proportional to the rate of flow of water being treated. Such equipment is manufactured by the International Filter Company, the Permutit Company and C. W. Sirch.

The fifth type of equipment consists of automatic apparatus controlled mechanically or electrically through the agency of small crest, turbine or propeller meters, connected on bypass lines around Venturi meters, main line orifices, or larger meters of the same type. Apparatus of this description is manufactured by the American Water Softener Company, the Builders Iron Foundry, Phipps and Bird, Inc. the Omega Machine Company, and the Wallace & Tiernan Company, Inc.

The convenient and reliable use of equipment for the application of hypochlorite solutions to water supplies requires that the solutions be sufficiently stable to permit their storage in tanks of considerable capacity, so that the solutions need not be prepared frequently. This situation made it desirable to study the stability of such solutions. The following data were collected by F. W. Gilcreas and his associates of the Division of Laboratories and Research of the New York State Department of Health. Only a brief summary of this study can be given in the time available, but the results are of distinct practical significance.

SODIUM HYPOCHLORITE

Commercial sodium hypochlorite solutions are available at most dairy supply houses. These solutions usually contain from 3 to 12 percent available chlorine and are quite stable, due to their high alkalinity. Freedom from suspended solids greatly simplifies their application to water supplies. The cost of these commercial solutions in terms of available chlorine, however, usually prohibits their use, except with the smaller supplies. It is possible, however, to rent

equipment from the Wallace & Tiernan Company, Inc. for a reasonable sum to make clear, sodium hypochlorite solutions at a very moderate cost. The principle involved is the patented Level process, in which chlorine gas is allowed to slowly enter a solution of sodium hydroxide to produce sodium hypochlorite.

CHLORIDE OF LIME

Chloride of lime is a mixture of calcium hypochlorite and excess lime. This widely distributed disinfectant may be purchased in grocery, hardward and drug stores. The available chlorine content of fresh material varies from about 25 to 37 percent. The compound is unstable and hence should not be stored for long periods of time. The excess lime is insoluble and hence solutions of chloride of lime contain considerable sludge which would lead to difficulty from the clogging of valves, orifices, etc. of control equipment, unless the sludge is settled and the clear supernatant liquid is discharged into the solution tank.

The stability of hypochlorite solutions is influenced by their initial strength, their temperature and alkalinity, and their exposure to light. Table 1 shows the stability of 1.39 percent strength chloride of lime solution for a period of 14 days, when exposed to temperatures of about 68°F. and 85°F. respectively, and when the solutions were exposed to or protected from light. The alkalinity of this solution was equal to about 0.18 percent calcium carbonate. It will be noted that the 7.2 percent loss of available chlorine, when the solution was exposed to light at the lower temperature, was over twice the loss when the solution was protected from the light. The loss was somewhat greater at the higher temperature, if allowance is made for evaporation, which occurred at a greater rate than the loss in chlorine, and hence an increase in the actual chlorine concentration occurred.

In general these results indicate that chloride of lime solutions may be stored at room temperature if protected from light, for a period of at least two weeks without a significant loss of chlorine.

CALCIUM HYPOCHLORITE

Two commercial forms of calcium hypochlorite contain 65 to 70 percent available chlorine, namely, HTH (High Test Hypochlorite) manufactured by the Mathieson Alkali Company, 250 Park Avenue, New York City, and Perchloron, manufactured by the Pennsylvania Salt Manufacturing Company, Philadelphia, Pa. Both of these

powders are more stable and more highly soluble than chloride of lime. Relatively clear solutions may be prepared by adding H.T.H. or Perchloron to the required amount of water, although it is the best practice to dissolve the powders in a small volume of water, and then to allow the sediment to settle. The clear supernatant liquid, decanted or siphoned from the mixing tank, should then be diluted with sufficient water to prepare the required quantity of solution.

TABLE 1

The stability of chloride of lime solutions where stored for two weeks at temperatures noted and when exposed to and protected from light

(All figures in percent)

	ORIGINAL STRENGTH	FINAL STRENGTH	LOSS
Exposed to light at 68°–70°F.			
Available chlorine	1.39	1.29	7.2
$Ca(OH)_2$	0.083	0.00	100.0
$CaCO_3$	0.071	0.05	29.6
Protected from light at 68°–70°F.			
Available chlorine	1.39	1.35	2.9
$Ca(OH)_2$	0.083	0.00	100.0
$CaCO_3$	0.071	0.03	57.9
Exposed to light at 84°–88°F.			
Available chlorine	1.39	1.26	9.3
$Ca(OH)_2$	0.083	0.01	88.0
$CaCO_3$	0.071	0.02	72.0
Protected from light at 84°–88°F.			
Available chlorine	1.39	1.43	
$Ca(OH)_2$	0.083	0.01	88.0
$CaCO_3$	0.071	0.07	1.4

The alkalinity of solutions of H.T.H. or Perchloron containing 1 percent available chlorine is about 0.25 percent, expressed as calcium carbonate. This alkalinity is sufficient to prevent an appreciable loss of chlorine for periods of two to three weeks. Solutions to be stored for periods longer than two to three weeks should be stabilized by the addition of soda ash according to the directions given by the manufacturers. The resulting calcium carbonate should be allowed

to settle and the clear, supernatant sodium hypochlorite solution should be siphoned into the control apparatus. Thirty gallons of 1 percent strength solution may be prepared by dissolving 4 pounds of H.T.H. or Perchloron and 3 to 3½ pounds of soda ash, in 30 gallons of water, according to directions.

The solutions of H.T.H. and Perchloron, stabilized with soda ash, were stored, as in the case of chloride of lime solutions, to determine their stability. The results of these studies are shown in tables 2 and 3. The values for chlorine content have been corrected for evaporation, determined by the increase in the alkalinity of the solutions

TABLE 2

The stability of a 5 percent solution of H.T.H. and soda ash when stored for 35 days at temperatures noted and when exposed to and protected from light

(All figures in percent)

STORAGE CONDITIONS	ORIGINAL STRENGTH	FINAL STRENGTH	FINAL STRENGTH CORRECTED FOR EVAPORATION	LOSS ACTUAL	LOSS CORRECTED FOR EVAPORATION
Exposed to light at 68°–74°F	4.96	4.57	4.45	7.8	9.4
Protected from light at 68°–74°F	4.96	5.00	4.88		1.6
Exposed to light at 85°–88°F	4.96	4.57	4.33	7.8	12.7
Protected from light at 85°–88°F	4.96	5.00	4.75		4.2

Note: This solution of H.T.H. and soda ash had an initial alkalinity equivalent to 1.96 percent sodium carbonate, and final alkalinities somewhat higher, due to evaporation. No appreciable loss of chlorine occurred during the first two weeks of storage.

resulting from evaporation. It will be noted from table 2 that the solution of H.T.H., having a 4.96 percent available chlorine content, lost 9.4 percent of its chlorine upon storage for 35 days, when exposed to light at a temperature of about 70°F. The same solution lost only 1.6 percent of its chlorine content when stored at the same temperature, but protected from light. The solutions were naturally less stable at the high temperatures of 85°F., especially when exposed to light, but the corrected loss of 12.7 percent during the 35 day storage period was surprisingly low. In fact the rate of evaporation was greater than the rate of loss of chlorine from the solutions protected

from the light, and hence there was an increase in the actual chlorine content of the solution, as in the case of chloride of lime. Detailed data are not tabulated, but there was practically no loss of chlorine during the first two weeks of storage, hence the values for the longest period are given to conserve space.

Table 3 gives corresponding values for solutions of Perchloron and soda ash. Practically identical results were secured, and hence they need not be discussed.

The freezing point of hypochlorite solutions may be lowered very economically through the use of calcium chloride, which is cheap

TABLE 3

The stability of a 5 percent solution of Perchloron and soda ash when stored for 35 days at temperatures noted and when exposed to and protected from light

(All figures in percent)

STORAGE CONDITIONS	ORIGINAL STRENGTH	FINAL STRENGTH	FINAL STRENGTH CORRECTED FOR EVAPORATION	LOSS ACTUAL	LOSS CORRECTED FOR EVAPORATION
Exposed to light at 68°–74°F	4.46	4.15	4.08	6.9	8.5
Protected from light at 68°–74°F	4.46	4.54	4.33		2.9
Exposed to light at 85°–88°F	4.46	4.08	3.94	8.5	11.7
Protected from light at 85°–88°F	4.46	4.65	4.49		

Note: This solution of Perchloron and soda ash had an initial alkalinity equivalent to 2.81 percent sodium carbonate, and final alkalinities somewhat higher due to evaporation.

No appreciable loss of chlorine occurred during the first two weeks of storage.

and which does not modify the disinfecting properties of the solution. The freezing point can be lowered to −22°F. through the use of sufficient calcium chloride to produce a 25 percent solution. Naturally it is not necessary in practice to reduce the freezing point to this very low value, but the prevention of freezing may be of great importance at some plants.

Calcium chloride, or some other similar inert, soluble substance is also useful in increasing the density of the solution, the specific gravity of which must be higher than that of water to prevent diffusion of water into the solution when one type of "displacement" apparatus

is utilized. One percent solutions are said to be adequate for this purpose, but it is an easy matter to add calcium chloride to hypochlorite solutions to produce a heavy solution of say 5 percent.

The practical conclusions of this study of hypochlorite solutions are that separate mixing tanks should be provided to permit the insoluble material being settled and the clear supernatant solution being discharged into larger storage tanks. The storage tanks should be protected from the light through the use of covers. Solutions of chloride of lime, and more especially those of H.T.H. and Perchloron may be stored in the dark at room temperature for periods of at least 2 weeks without the loss of available chlorine being of practical significance. Solutions stored for periods exceeding two to three weeks should be stabilized through the use of soda ash, in which case the loss of chlorine would be of little significance during storage periods up to five weeks. The stability of solutions so stabilized permits storage for appreciable periods of time, thus minimizing the labor involved in preparing solutions.

GENERAL SUMMARY

There has been a great need of equipment for the economical chlorination of small water gravity supplies because heretofore, with one exception, automatic equipment was designed to treat only the larger supplies. There is now available, however, equipment of both the liquid chlorine and hypochlorite solution types which will chlorinate successfully even the smallest of public water supplies. Both automatic and manually controlled apparatus are available to meet the various hydraulic conditions encountered in practice.

Acknowledgment is made to Mr. F. W. Gilcreas and his Associates of the Division of Laboratories and Research of the New York State Department of Health for their coöperation in making a thorough investigation of hypochlorite solutions, and also to the representatives of the manufacturers of equipment in furnishing detailed information.

APPENDIX

BRIEF DESCRIPTION OF HYPOCHLORITE SOLUTION FEEDERS MANUFACTURED BY ELEVEN COMPANIES AND LIQUID CHLORINE FEEDERS MANUFACTURED BY THREE COMPANIES

American Water Softener Company, Philadelphia, Pa.

The Magnetic Proportioner of this company consists of a solution tank, the rate of flow from which is controlled by a feeding tube which

is lowered electrically by a telechron clock for manual control equipment, or by the Magnetic Proportioner, which is in circuit with a commutator on a small water meter through which proportional flow passes. This apparatus may also be controlled by small motor-driven "Contactor," which automatically functions during periods of fire flow, being controlled by a mercoid switch on an automatic check valve. A solution pump or injector is furnished separately when needed to force the solution into water under pressure.

Builders Iron Foundry, and Proportioneers Inc., Providence, R. I.

The chloro-O-Feeder of these firms consists of a diaphragm solution pump driven by a diaphragm water piston of larger area. The length of the stroke may be varied manually to control the dose, and the number of strokes is varied automatically by direct coupling to reciprocating pumps, or by a special gear arrangement attached to displacement meters, through which proportional flow passes. The equipment will force hypochlorite solution into water under a pressure as high as 100 pounds per square inch, and hence a separate solution pump is not needed.

The Adjust-O-Feeder of these firms is a motor driven, variable stroke, solution pump, which can be used to provide manual control chlorination, or which may be used in connection with a mercoid switch, which would automatically function when a check valve is opened during periods of very heavy flow, or during fires. A Chloro-O-Feeder would be used with the Adjust-O-Feeder to provide proportional chlorination during periods of normal flow. These two pieces of equipment may be utilized in a number of combinations to provide automatic, proportional feed of hypochlorite solutions over a wide range.

Beaumont Apparatus Company, 1505 Race Street, Philadelphia, Pa.

The Drip Feed Chlorinator of this company provides manual control chlorination, where the dose of hypochlorite solution is manipulated through the use of multiple orifices and also by means of a variable head on the orifices. A solution pump or injector would be needed to introduce solution under pressure.

Filclor Company, Philadelphia, Pa.

The equipment of this company for the manually controlled application of liquid (gaseous) chlorine to water consists of both the dry-

feed and solution-feed types. A filter for chlorine gas and an electric heater are provided to minimize difficulty from clogging. Doses as low as about $\frac{1}{4}$ pound of chlorine gas per day may be controlled.

Hills-McCanna Company, 53 Park Place, New York City

The types L & G pumps, of special "Hastelloy" metal, made by this company, are variable stroke pumps suitable for forcing hypochlorite solution into water supplies. The pumps may be belt or motor driven, or connected directly to reciprocating water pumps. The stroke may be manually controlled to vary the dose of solution pumped from a storage tank.

Omega Machine Company, 4010 Penn Avenue, Kansas City, Miss.

The Precision Feeder of this company consists of a hypochlorite solution tank, a controlled feeding tube, which is lowered by manual control mechanism, consisting of a telechron clock, or by a solonoid magnet connecting to a mercoid switch on a water meter, whereby proportional feed is secured. The Proportional Feeder is an automatic equipment, where the pressure causing the flow of hypochlorite solution is varied in conformity with changes in flow of water over a weir, or through an orifice or Venturi meter. A solution pump or injector would be needed with this equipment when water under pressure is being treated.

Pardee Engineering Company, Long Island City, N. Y.

This company manufactures manually controlled equipment of both the dry-feed and solution-feed types for the application of liquid (gaseous) chlorine doses exceeding about $\frac{1}{4}$ pound per day. A vacuum type of solution feed equipment of large capacity is also manufactured.

The Permutit Company, 440 4th Avenue, New York City

The displacement type of equipment of this company is proportionally controlled by orifices or Venturi meters, whereby hypochlorite solution is displaced by water at a rate proportional to the flow of water being treated. There are no moving parts to the equipment and no solution pump is required.

Phipps and Bird, 140 Virginia Street, Richmond, Va.

The Solution Feeder manufactured by this company consists of manually controlled and automatic apparatus for the control of

hypochlorite solutions flowing from a storage tank. There are no moving parts. A solution pump or injector is required when water under pressure is treated.

International Filter Company, Chicago, Ill.

The D-D Feeder manufactured by this company is of the proportional displacement type feeding hypochlorite solutions, which are controlled by an orifice or Venturi meter. There are no moving parts and no solution pump is required.

The smaller DMO feeder is suitable for very small supplies, where the total amount of water treated is passed through a displacement meter, which provides automatic proportional feed of hypochlorite solutions.

C. W. Sirch, 126 W. Third Street, Los Angeles, Cal.

The Paradox chlorinator manufactured by this company is of the displacement type, where proportional feed of hypochlorite solutions is secured through the use of a Pitot tube, orifice, or Venturi meter. There are no moving parts and no solution pumps are required.

Wallace & Tiernan Company, Inc., Newark, N. J.

This company manufactures equipment for the application of both liquid (gaseous) chlorine and hypochlorite solutions to water supplies.

The pedestal chlorinator, of both the dry-feed and solution-feed type, provides manually controlled application of liquid chlorine doses exceeding about $\frac{1}{4}$ pound per day.

The vacuum type chlorinator may be secured in either manual or automatic control types for applying liquid chloring in doses exceeding about 1 to 2 pounds per day.

The Rotor type of equipment provides automatic and manual control of liquid chlorine to supplies with doses varying from the smallest to about 5 pounds per day.

The Chloroclock manufactured by this company is a manually controlled device, where a telechloron clock controls the rate of feed of hypochlorite solution. An injector or solution pump is required when water under pressure is treated.

The Chlorometer of this company provides proportional flow of hypochlorite solution through the use of displacement meter on the main pipe lining, or a smaller meter on a by-pass line around an orifice

or Venturi meter. An injector or solution pump is required when water under pressure is treated.

The Electrolytic Cell manufactured by this company is available for the chlorination of even the smallest water supplies. Direct current is required, so a motor generator set, rectifier, or storage batteries would be required when DC current is not available.

Wilson Chlorinator and Sanitation Corporation, Buffalo, N. Y.

This company manufactures several types of solution feeders where the rate of flow is manually controlled through the use of calibrated orifices. Several types of solution pumps are available with variable capacities to provide flexibility in treatment.

HANDLING CHLORINE TO AVOID TROUBLE

By L. L. Hedgepeth

(Technical Service Department, Pennsylvania Salt Manufacturing Company, Philadelphia, Pa.)

It has been said that erroneous ideas are easy to acquire and hard to lose. This statement is particularly applicable to chlorine, which on account of its extreme reactivity has developed marketing complexities peculiar to itself.

A shipment of alum is either good or bad, depending on its particle size, solubility or concentration; soda ash is acceptable or unacceptable, depending on its Na_2O content or free flowing characteristics; ammonia either contains not more than 0.03 percent non-condensibles or is rejected without further argument; but chlorine—the name of its sins is legion—ranging from bleaching goldfish to the operators' premature loss of interest in those things that make the world go round. Most of the comments on chlorine are justified but we encounter many peculiar statements. For instance:

> The head of a chemistry department at a State Teachers College complains that the chlorine furnished his institution is of old stock and, because of the decay of age, is only 40 percent active. (*Scheele and Davy must have shivered in their graves at that one.*)

or—

> "The chlorine is weak and must be adulterated because last week when the temperature was below zero its vapor pressure was only 14 pounds." (That also from a chemist.)

or—

> "We must discontinue using this chlorine because impurities in it are so excessive that even when applied to our water at 0.6 p.p.m. it has caused the condensed steam lines in the hotel heating system to rust out before the live steam lines." (That from a stationary engineer) and so on ad infinitum.

It is the object of this paper to reiterate concisely those pertinent physical and chemical facts necessary to intelligent interpretation of chlorination variables, to separate fact from fancy in operating irregu-

larities and to discuss convenient successful installations for handling the ton containers of this commodity.

PHYSICAL AND CHEMICAL DATA

Liquid chlorine is a moisture free liquefied gaseous element, remaining liquid at temperatures below 293°F. when confined under its

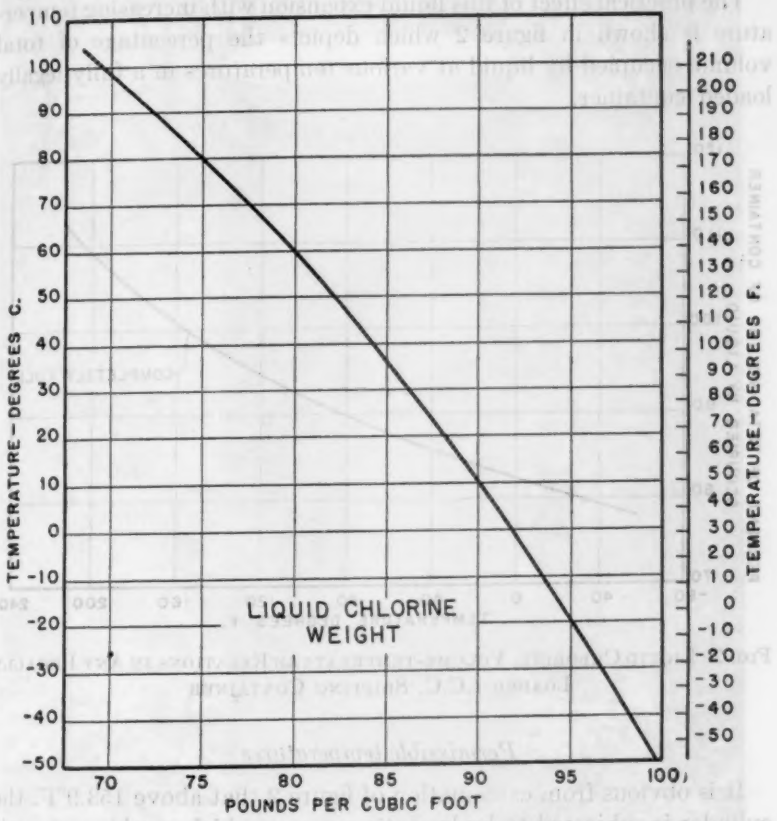

FIG. 1

vapor pressure in suitable containers. Its vapor gauge pressure is a function of temperature only, ranging from 39.4 at the freezing point of water to 602.4 pounds at the boiling point of water. When the vapor pressure is released it boils steadily, discharging itself as a gas.

It is shipped under the rigid restrictions of the I.C.C. in steel containers, varying from one pound each to 30 ton single unit tank cars,

all tested periodically to 500 pounds per square inch, all loaded with not more than 125 pounds of chlorine for each 100 pounds of water capacity.

The volume weight of the liquid changes inversely with the temperature as shown in figure 1 varying from 91.8 at 32°F. to 78 pounds per cubic foot at 153.9°F.

The practical effect of this liquid expansion with increasing temperature is shown in figure 2 which depicts the percentage of total volume occupied by liquid at various temperatures in a fully legally loaded container.

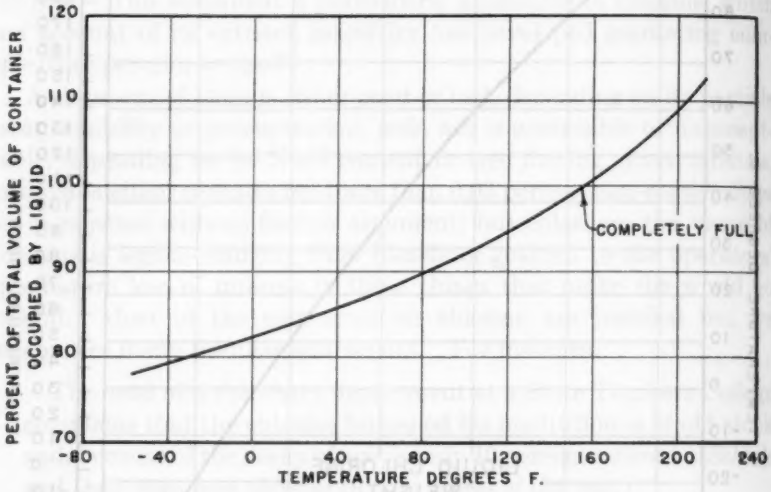

FIG. 2. LIQUID CHLORINE, VOLUME-TEMPERATURE RELATIONS IN ANY LEGALLY LOADED I.C.C. SHIPPING CONTAINER

Permissible temperatures

It is obvious from examination of figure 2 that above 153.9°F. the cylinder is subjected to hydrostatic pressure which would rupture it were it not for the fusible plug which softens at higher temperatures. Further consideration of this expansion will reveal that if more than its rated contents is placed in a cylinder, disastrous rupture may occur at temperatures far below the fusion point of the safety plug—even at room temperatures.

For this reason cylinders should not be filled or contents transferred in the users plant. It is both illegal and dangerous.

Effect of excessive heating

Steel is not attacked by dry chlorine at ordinary temperatures. However, at higher temperatures (given by one observer as above

FIG. 3

194°F.) it burns brightly in dry chlorine, producing anhydrous ferric chloride with great evolution of heat. We have one case on record of a steel valve failure because of frictional heat from high chlorine

gas velocity through the valve, igniting the steel seat. A heat ruptured 150 pound chlorine cylinder is shown in figure 3 planted in the front yard of the filter plant of the Indianapolis Water Company, as a warning to operators not to heat cylinders with a blow torch. The cylinder wall was heated to a point where it burned in the dry chlorine, producing rupture.

Equipment and lines carrying dry chlorine should not be exposed to excessive heat.

Disposal facilities for leaking chlorine

Because of concentration of 2000 pounds chlorine in one container, the adoption of a water plant chlorination layout for ton containers should include disposal equipment for leaking chlorine.

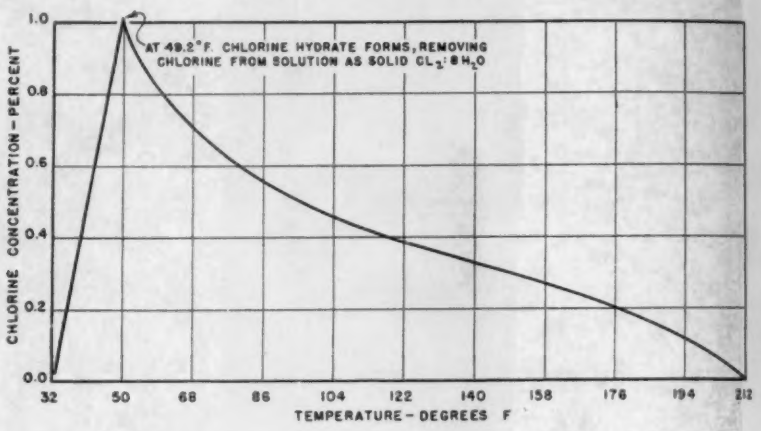

FIG. 4. SOLUBILITY OF CHLORINE IN WATER 0 TO 212°F.

One frequently observes water showers installed or specified as protection in case of chlorine container rupture. The water so discharged is, in many cases, depended upon to serve as a solvent and vehicle for safely disposing of waste chlorine. The flimsy questionable protection so afforded is pictured in figure 4 which indicated the maximum quantity of chlorine which can be dissolved by water under the most favorable conditions. It is doubtful under the usual showering and flooding conditions if 0.1 percent absorption can be exceeded. Practically interpreted for a ton unit this means that 250,000 gallons will be required—an absurd quantity.

Showers are of real value in clearing the air after a leak, but *unless*

operated in conjunction with an adequate forced ventilation system they constitute a hazard in that the leak rapidly becomes greater in the presence of moisture. They are also useful in disposing of pooled liquid chlorine in case of serious rupture by converting it into the more stable and easier handled chlorine hydrate.

Successful ton container protection items have been:

(1) Fresh air vents at top of room—discharge ducts at floor level. (Chlorine gas is 2½ times heavier than air.)

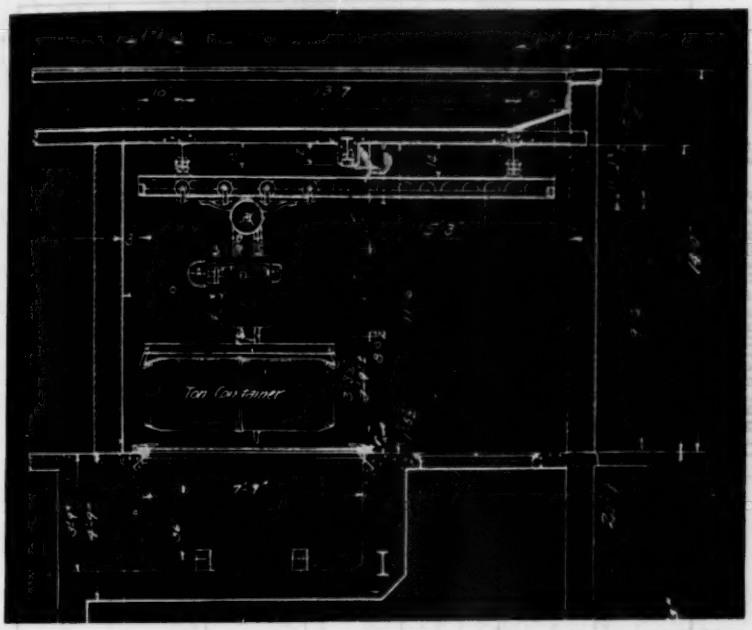

FIG. 5

(2) A fresh air fan or chlorine resistant eduction fan which will completely change the room's air every two minutes.

(3) Stream eduction ejectors which solve simultaneously both the evacuation and disposal problem, since chlorine is almost instantaneously united with the steam to form the less objectionable chlorine acids.

(4) The discharge ducts to terminate at a sufficiently high point to insure atmospheric dilution satisfactory for the vicinity.

(5) The discharge ducts to terminate in a sewer carrying domestic sewage.

(6) Storing and servicing each container in separate gas-tight vaults built to withstand an internal pressure of 125 pounds per square inch, and piped to feed a chlorinator with either gas from the container or gas from the vault. Figure 5 illustrates such a vault designed for Asbury Park, New Jersey, by Remington, Vosbury and Goff.

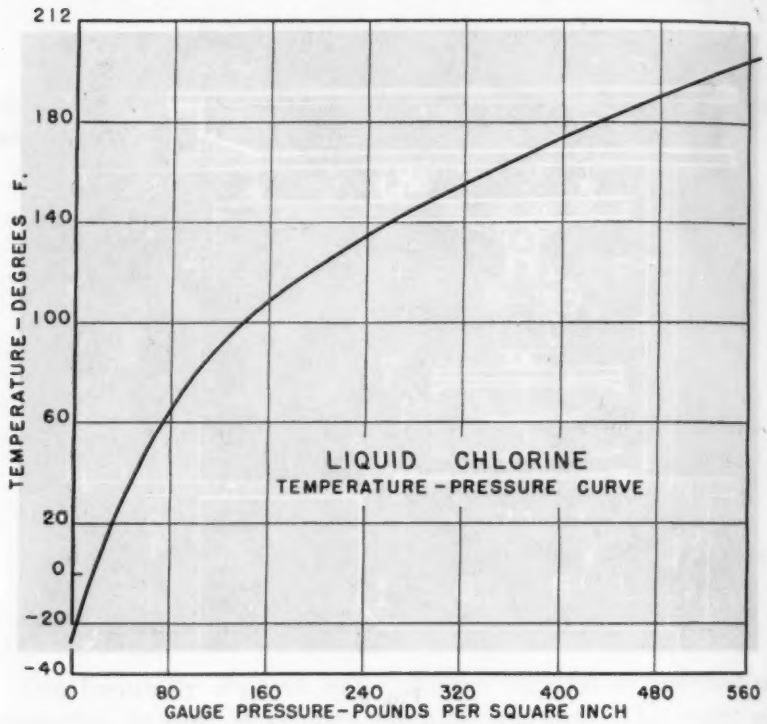

FIG. 6

Machine stoppage

Machine plugging is usually due to atmospheric moisture entering the chlorinator during cleaning or shut downs, the chlorination of lubricants or cleaning solvents left in the machine, or to condensing liquid chlorine redissolving waxes deposited from the gaseous chlorine over several months operation.

A generalized diagram is shown in figure 6 of the most perplexing

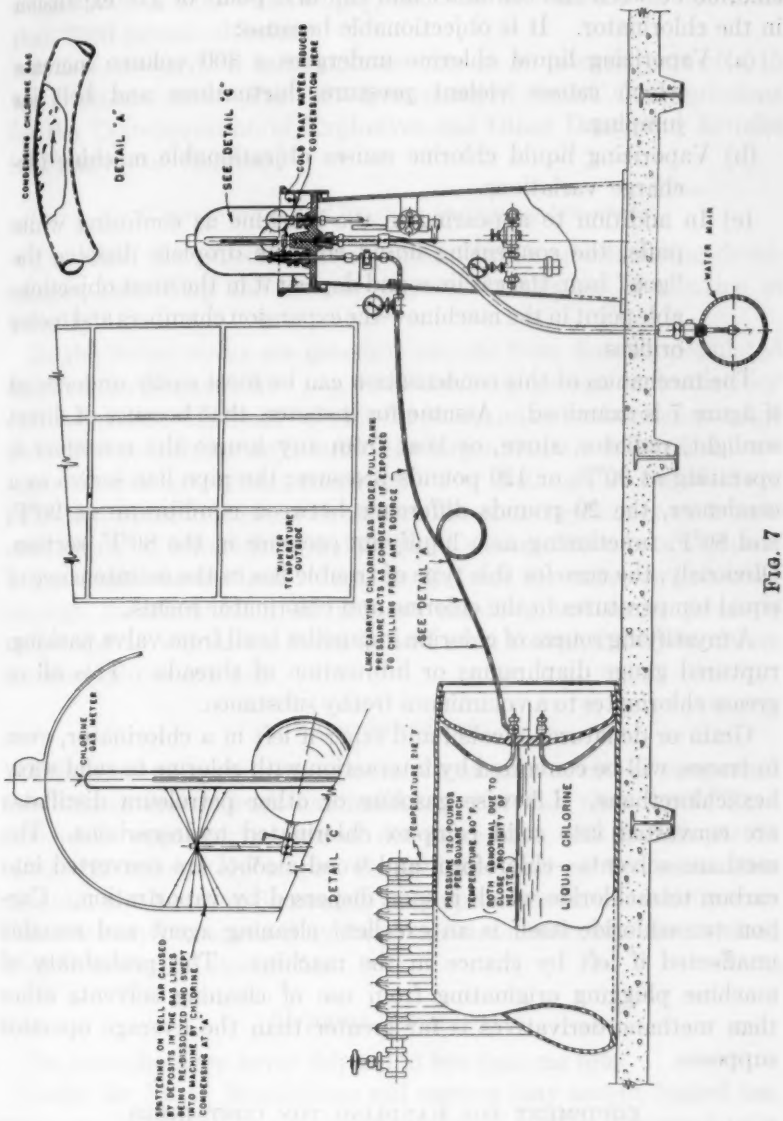
CONDENSING CHLORINE GAS
DETAIL "A"
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
WATER MAIN
WINTER TEMPERATURE OUTDOOR
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE ACTS AS CONDENSER IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
CHLORINE GAS METER
DETAIL "C"
SOOTTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO MACHINE BY CHLORINE CONDENSING AT "A"
TEMPERATURE 216° F
PRESSURE 120 POUNDS PER SQUARE INCH TEMPERATURE 80° F.
(BOTH ABNORMAL DUE TO CLOSE PROXIMITY OF HEATER)
LIQUID CHLORINE

FIG. 7

and prolific source of chlorine operating trouble, i.e., condensation of chlorine between the container and the first point of gas expansion in the chlorinator. It is objectionable because:

(a) Vaporizing liquid chlorine undergoes a 300 volume increase which causes violent pressure fluctuations and bell jar jumping.

(b) Vaporizing liquid chlorine causes objectionable machine discharge variations.

(c) In addition to appearing in the machine as confusing white puffs, the condensing liquid chlorine droplets dissolve the "goo" from the gas lines and deposit it in the most objectionable point in the machine—the expansion chambers and meter orifices.

The mechanics of this condensation can be most easily understood if figure 7 is examined. Assume for instance, that because of direct sunlight, radiator, stove, or heat from any source the container is operating at 90°F. or 120 pounds pressure; the pipe line serves as a condenser, the 20 pounds difference between equilibrium at 90°F. and 80°F. functioning as a liquifying pressure in the 80°F. section. Obviously, the cure for this type of trouble lies in the maintenance of equal temperatures in the chlorine and chlorinator rooms.

A mystifying source of chlorine impurities is oil from valve packing, ruptured gauge diaphragms or lubrication of threads. This oil or grease chlorinates to a voluminous frothy substance.

Grain or denatured alcohol and ether if left in a chlorinator, even in traces, will be converted by interaction with chlorine to solid waxy hexachlorethane. Likewise gasoline or other petroleum distillates are converted into solid complex chlorinated hydrocarbons. The methane solvents—chloroform and wood alcohol are converted into carbon tetrachloride which is soon dispersed by vaporization. Carbon tetrachloride itself is an excellent cleaning agent and remains unaffected if left by chance in the machine. The probability of machine plugging originating from use of cleaning solvents other than methane derivatives is far greater than the average operator supposes.

EQUIPMENT FOR HANDLING TON CONTAINERS

The chlorine ton container is a steel cylinder 6 feet 8 inches long, 30 inches diameter, with concave ends, fitted with three fusible plugs spaced 120 feet apart in each end and two valves and eduction pipes

in one end. It has a total capacity of not less than 25.63 cubic feet, weighs 1300 pounds when empty, and may be loaded with not more than 2000 pounds chlorine.

It is authorized for rail shipment only as an integral part of a 15 ton multi-unit car. (Par 1861-A amended of the I.C.C. Regulations for the Transportation of Explosives and Other Dangerous Articles by Freight and Express.)

Consumption and location justifying ton units

The use of the ton container at water plants is an interesting development paralleling the general increase in the use of chlorine in industry.

As the water works are generally remote from densely populated districts the ton container is a vital factor in the cost and efficiency of chlorination. It is not suitable for plants using a minimum average under 200 pounds per day, but in the larger plants it is justified from safety as well as cost consideration. For instance, at the Baldwin Filtration Plant in Cleveland, sixteen 150 pound cylinders with their multiplicity of connections and frequent changes have been replaced with a single one ton unit. In cases like this, the decrease in hazard through the elimination of frequent handling and many joints is considered to reduce the total hazard even though 2000 pounds are concentrated in one unit.

Vaporization rate

Divergence of opinion exists as to the maximum rate of evaporization. Some recent work has indicated that in a room at 70°F., a continuous vaporization rate of not more than 420 pounds per 24 hours will completely empty the cylinder and at the same time maintain not less than 35 pounds gauge pressure on the chlorinators. This rate may be increased by forced air circulation, such as a stream of air from a small electric fan.

Shipping restrictions

Ton containers are never shipped in less than car lots.

Under the I.C.C. Regulations rail carriers may accept loaded ton containers in carload lots only and shipments may be consigned only to private sidings or to approved public sidings.

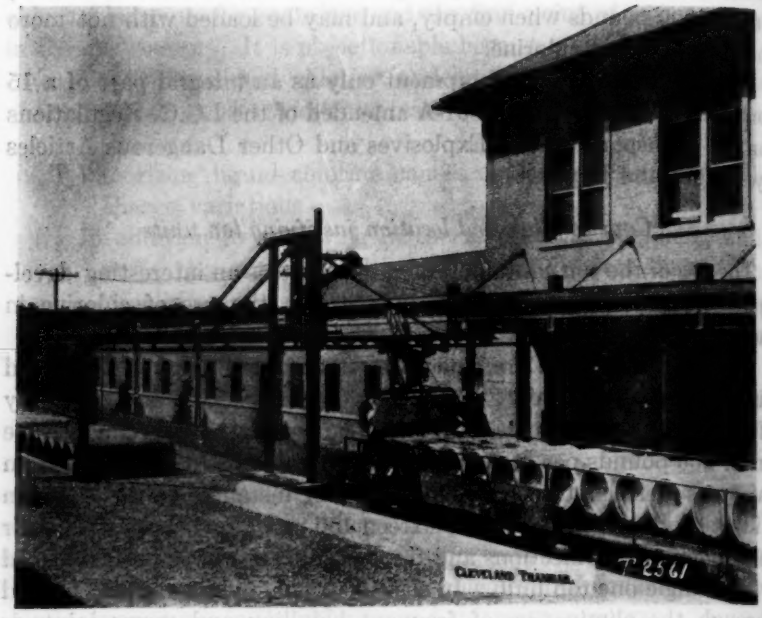

FIG. 8

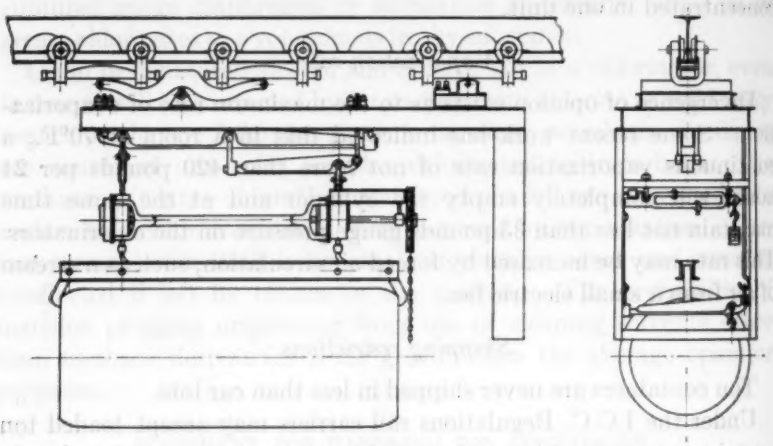

FIG. 9. HAND OPERATED TRAVELING HOIST WITH BEAM SCALE AND CHLORINE TON CONTAINER GRAB

Unloading and handling equipment

Obviously, the best method of handling the containers in the plant differs widely because of individual conditions—many ingenious installations have been devised. The Richmond, Va., car-unloading installation for direct placement on the storage platform without intermediate trucking is shown in figure 8.

At the Allentown Sewage Disposal Plant hoisting and transportation equipment has been made unnecessary by the construction of a

FIG. 10. SHADES VALLEY PLANT. SEWAGE TREATMENT WORKS, BIRMINGHAM, ALABAMA

simple platform, the deck of which is two inches lower than the floor of the delivery truck. Fulls are always delivered to the east end and empties taken from the west end. The containers are always serviced from west to east. This installation obviously has the advantage of extreme simplicity and the disadvantage of exposure to the weather. Condensation difficulties in hot weather have been eliminated by erecting the gas line in a continuous upgrade from the platform, thus allowing the condensate to flow back into the cylinder. Cold weather difficulties have not been encountered.

A convenient combination of scales and traveling hoist for interior use (figure 9) has been devised by Cleveland Tramrail for plants with insufficient floor space for both scales and storage.

A combination of outside storage and inside use at Shades Valley Sewage Disposal Plant, Birmingham, Ala., is shown in figure 10. In this installation containers are maneuvered on a platform by rolling, transported to and from chlorinator room by a single traveling hoist of minimum rail length.

This is a very simple installation.

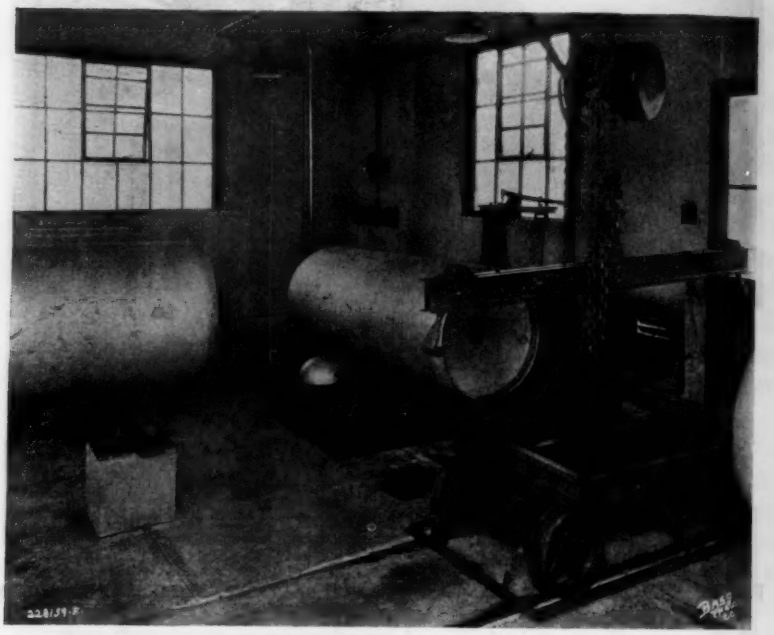

FIG. 11

At the Indianapolis Water Plant individual factors made the most desirable solution a combination of outside storage and transportation to and from the chlorine room on a small platform height dolly travelling on rails (figure 11).

The pictures in figures 12 and 13 illustrate the ingenious combination of hoists, dolly and overhead rails to handle ton containers in the Baldwin plant at Cleveland through a tortuous route between the

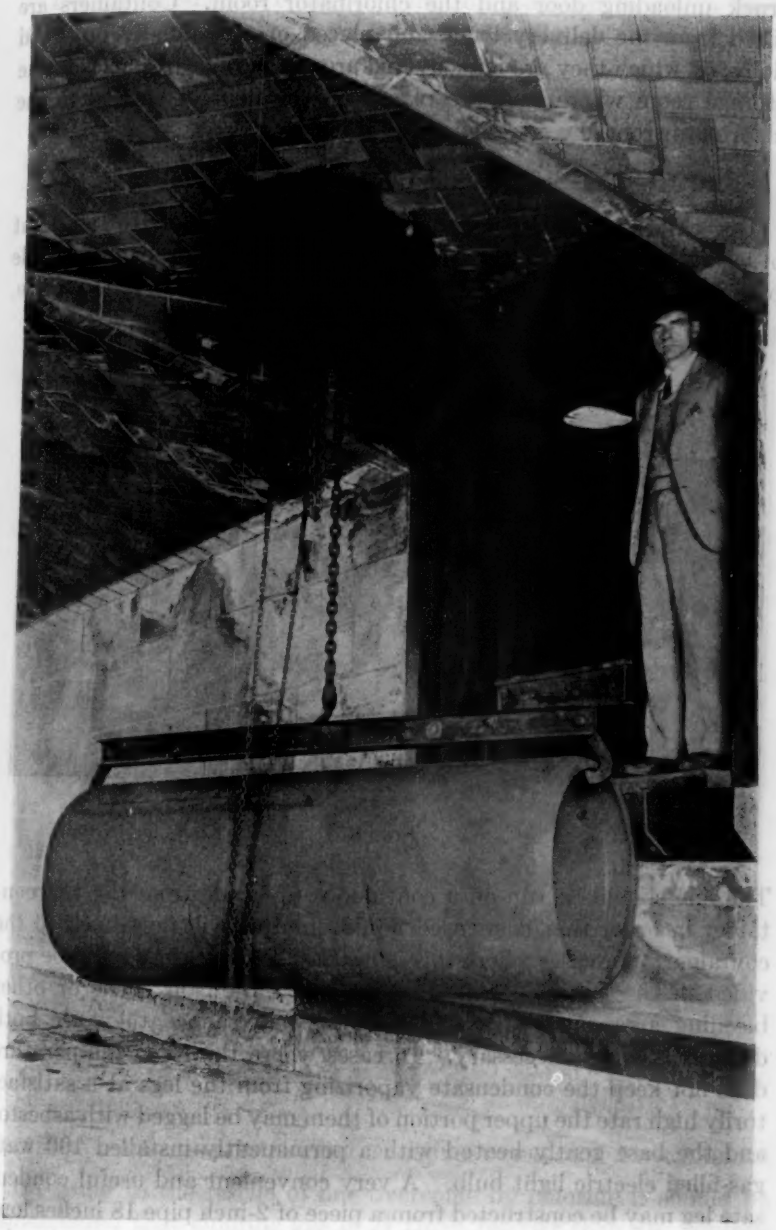

FIG. 12. TON-CONTAINER LIFTED

truck unloading door and the chlorinator room. Containers are lifted from the delivery truck and placed on a manually propelled dolly, on which they are maneuvered around various obstacles to the storage room where they are placed on the floor or carried to the chlorinator room by a traveling chain hoist.

PIPING DETAILS

Dry chlorine gas may be conducted from containers to the point of use in either wrought iron, steel, copper, or any other serviceable pipe provided it is of the extra heavy variety for 250 pounds service.

FIG. 13

The line should be run on a continuous up-grade from the ton container in order that condensed liquid chlorine will flow back to the container. In cases where this is impossible drip legs should be provided in the low points of the pipe line. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. In cases where the room temperature does not keep the condensate vaporizing from the legs at a satisfactorily high rate the upper portion of them may be lagged with asbestos and the base gently heated with a permanently installed 100 watt gas-filled electric light bulb. A very convenient and useful condensate leg may be constructed from a piece of 2-inch pipe 18 inches long capped on the bottom and screwed into the low point of the line by means of suitable reducing fillings.

The best method of connecting the ton container to such a line is shown in figure 14 taken from the same installation at Indianapolis.

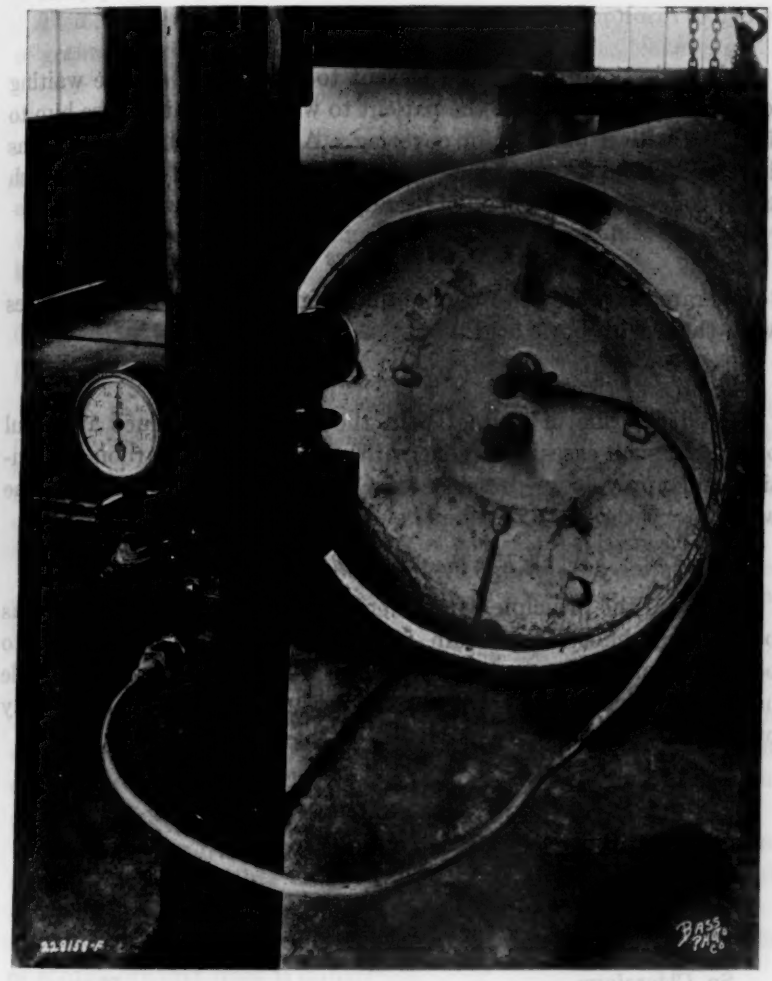

FIG. 14

ACCIDENTS AND TREATMENT OF PERSONS OVERCOME BY CHLORINE

On going to the rescue of one overcome by chlorine it should be remembered that chlorine gas is $2\frac{1}{2}$ times heavier than air, concen-

trating in the lower parts of the room. Therefore, *keep the head as high as possible.* The gas mask should be well adjusted to the contour of the wearers face.

First aid measures

Call a physician or get the patient to a hospital. While waiting for the physician, remove the patient to warm fresh air, cause him to lie down with a blanket for covering. Administer "Anti-Chlor" as directed. If no "Anti-Chlor" is available give a mild stimulant such as hot coffee or a tablespoon of brandy in warm water.

For the eyes

It is rare that the eyes are more than slightly irritated, in such cases wash them with boric acid.

For the skin

Liquid chlorine in contact with the skin may produce a painful burn. In such cases neutralize with weak sodium bicarbonate solution and apply loose dressings of Carron Oil (linseed oil and lime water.)

For the nose and throat

These are the principle parts affected. Anti-Chlor as directed has been found effective. Steam from tincture of benzoin added to boiling water is very soothing. In cases where these are not available have the patient breathe the vapors of warm Vick's Vaporub or any other good menthol salve.

ANTI-CHLOR (2 LITERS)

Water	1485 cc.
Sugar	45 grams
Tincture Lavender, Co	37 cc.
Sp. Ammonia Aromatic	56 cc.
Alcohol (Ethyl)	333 cc.
Oil of peppermint	37 cc.
Sp. Chloroform	55 cc.

Add Oil Peppermint to the Alcohol, then the Sp. Chloroform, then Spirits of Ammonia and Tr. Lavender Co. in the order given. Stir after each addition. Next add this mixture to the water in which the sugar has been dissolved.

Label: "ANTI-CHLOR" "Shake well before using."

Dosage: One tablespoon at 15 minute intervals until relief is obtained, or for one hour.

Keep patient quiet and warm.

To make spirits of chloroform.—Add 60 cc. of chloroform to 940 cc. of grain alcohol.

Probable after effects

Chlorine is not a poison, its action being primarily one of irritation to the mucous membrane. Its action is not cumulative and in most cases complete recovery is made. Employees with tendencies towards respiratory disturbances, particularly asthma, should not be given chlorine duties.

In a War Department study of the Residual Effects of Warfare Gases, 8 to 10 years after gassing, Gilchrist and Matz conclude in part:

"5. As a result of an intensive clinical study of the after histories of 96 men who had been gassed with chlorine, it was found that 9 showed definite anatomic or symptomatic residua which were attributable to gassing. In 7 instances the relationship of the disabilities to chlorine gassing was considered questionable. In 80 instances no relationship was found between the disabilities present at the time of this study and chlorine gassing."

"4. The method of study of these cases precludes the drawing of statistical conclusions, inasmuch as the patients selected were those who were most likely to have residua due to gassing."

SUMMARY

1. Because of its extreme reactivity liquid chlorine is a perplexing commodity to sell and service. Most of its operating difficulties could be avoided by a fuller understanding of its physical and chemical behaviour.

2. Shipping containers are only partially loaded to avoid hydrostatic pressure resulting from thermal expansion—containers should not be refilled or contents added to in a users plant.

3. Dry chlorine will react with steel above 194°F. Direct heating of containers and lines is dangerous.

4. Ton container installations should include positive ventilation devices which change the air every two minutes. Ceiling water showers are of little value except to clear the air and hydrate pooled liquid chlorine.

5. Higher temperatures on chlorine containers than on the chlorine pipe line or chlorinator will cause liquefaction in the cooler portions of the line or in the chlorinator.

6. Liquid chlorine entering a chlorinator dissolves the "goo" from the lines and deposits it in the diaphragm orifices or on the bell jar. It causes violent machine fluctuation.

7. Chlorine "goo" frequently originates from valve packing oil, diaphragm oil, grain alcohol, ether, or lubricants left in the chlorinator.

8. The methane derivatives—chloroform, wood alcohol or carbon tetrachloride are not converted into troublesome solids. They are the only safe chlorine equipment cleaners.

9. Ton containers can be accepted by rail carriers only in carload lots and the only when consigned to a private or approved public siding.

10. They are not advisable in plants using less than an average of 200 pounds per day. In larger plants the simplicity of connections and decreased handling renders the ton container an attractive package of chlorine.

11. Maximum continuous vaporization rates vary with the room temperature and air circulation. With normal circulation and temperature (70°F.) 420 pounds discharge per 24 hours is a dependable rate to maintain working pressure and empty the container completely of liquid chlorine.

12. Various types of handling equipment and ingenious installations are shown.

13. Piping may be either extra heavy wrought iron, copper, or steel. It should be run upgrade from the cylinder or condensation legs provided in all low points.

14. First aid measures are outlined.

ACKNOWLEDGMENTS

Acknowledgments for assistance in collecting the illustrations shown herein and the information used are made to L. H. Enslow, Editor of Water Works & Sewerage; William C. Lawrence and Mathew Braidech of the Baldwin Filtration Plant, Cleveland, Ohio; Marsden C. Smith, Engineer of Gas & Electricity, Richmond, Va.; A. E. Creasey, Technical Service Engineer, Cleveland Tramrail Co.; Harry E. Jordan, Superintendent of Filtration, Indianapolis Water Co.; Paul Blattler, Remington, Vosbury & Goff; Harry J. Krum, City Chemist, Allentown, Pa., and D. P. Smith and F. H. Steele of Pennsylvania Salt Manufacturing Company.

DISCUSSION OF PAPERS ON THE MECHANICS OF CHLORINATION

By Charles E. Trowbridge

(*Sanitary Engineer, American Water Works and Electric Company, New York, N. Y.*)

There are certain disagreeable features and elements of danger connected with the application of chlorine, because of its active properties, which cause trouble for the plant operator.

In the first place, all employees should receive instructions so they will have a complete understanding of the character of chlorine gas and its properties. Otherwise they handle it with a certain amount of fear based upon their own unpleasant experiences or the experiences of others.

For example, when it is explained that chlorine is not a poison gas, but if breathed into the lungs the chlorine acts towards suffication by expelling the air, because chlorine is so much heavier than air, the employee can be taught to handle it intelligently and to overcome any fear he may have had. If he fully understands the active properties of the gas, it is not difficult to teach the proper safeguards and methods to be used in handling chlorine.

The instruction should be complete, for in the handling of chlorine a little knowledge may be dangerous. It has often led to carelessness and a foolhardy exposure to the gas, which would otherwise be avoided.

The instructions should cover the use of the gas mask, how and when it should be used. After the mask has been used to shut off the escaping gas at the tank valve, the gas should be allowed to leave the room before the repairs to the equipment are begun. If a sudden leak develops while working on the equipment, the operator should be instructed to leave immediately to put on the gas mask.

There should be duplicate equipment in the sterilization plant for safety reasons as well as to insure against interruptions in the treatment.

Repairs of all kinds, including emergency repairs should be made

without haste, for attempts at speed usually lead only to greater difficulties in the repairs, and longer periods when the equipment is out of service.

Each employee should understand the reasons for the corrosive properties of chlorine, so that he will appreciate the importance of the proper care of the equipment, and thus provide for his own safety and add to the means of handling chlorine to avoid trouble.

Mr. Cox and Mr. Hedgepeth have both made an interesting and a valuable contribution to the important subject of chlorination. As an operator, I know you are going to find their papers more valuable when you have them available in *The Journal*, and can read them carefully as I have been able to do before the preparation of this discussion.

A REVIEW OF THE STATUS OF THE AMMONIA-CHLORINE PROCESS

By Marsden C. Smith

(*Engineer of Water and Electricity, Richmond, Va.*)

This review of the status of the ammonia-chlorine process is based upon the operation of seventeen water purification plants in the United States and Canada. Its purpose is not to express the personal opinions of any individual, but rather to determine what has been found to be the true value of the process, and the practical methods adopted for its use and control.

Before proceeding, allow me to express the appreciation of the author to the many gentlemen who have, by their complete response, made this review possible.

HISTORY

Historically, the combination of ammonia and chlorine in the formation of chloramines and chlorides of ammonia and nitrogen is not new. Race seems to have been first (1916) to use the process in a public water supply. Then followed the use of ammoniation by Houston and Adams in England, and by Ruth, McAmis, Spaulding, Lawrence and others during the period 1926–29, which attracted wide attention and much enthusiasm.

Naturally there followed a period of much confusion as many plants attempted to apply, too literally, the experiences of the pioneers. For this cause many abandoned the process as quickly as they had adopted its use. But when the real value of the process in their individual plants was determined, they now find it of great assistance in plant operation. Today the ammonia-chlorine process is widely used and its limitations are as well understood as its merits.

Since conditions are so variable in the widely separated water purification plants, no uniformity of practice or results may be expected; however, many generalized conclusions may be drawn that are both of interest and value.

PURPOSE

The prolonged sterilization obtained by the process is the most general and principal reason for its use.

Where the untreated water supply contains phenols or allied compounds of either industrial or natural origin, the addition of chlorine for sterilization often produces extremely disagreeable tastes and odors. It has been conclusively proven that in such cases the use of ammonia in addition, and preferably prior, to the chlorine will almost always prevent this taste amplification. However, where the cause of the taste and odor is other than this apparently limited class of compounds, the process is virtually useless as a means of elimination.

There is a difference of opinion as to its value in algae control. Brown, at Rodendo Beach, California, successfully uses the process for the *sole* purpose of the control of iron bacteria. Jordan, Indianapolis, reports, "Both algae and soil type of bacteria grew luxuriantly, so early in July, 1932, the ammonia treatment was discontinued and not resumed until autumn." At Richmond we have almost eliminated the plankton in the open, shallow aerator basin at the plant, but have observed a new growth, a typical moss. This moss produces none of the usual objectionable characteristics of water growths, but is, of course, undesirable in the finished water basins.

Experience has shown that decreasing the ratio of ammonia to chlorine, even though the orthotolodine indicated residual is the same, the so-called excess chlorine thus obtained is quite effective in the control of all growths. Of course, where excess ammonia is required for taste/odor prevention, this procedure is impractical.

One of the most perfect examples of the necessity of determining the application for each plant is that of Brown, previously mentioned. There the process is used only to control iron bacteria and, in direct conflict with the above conclusion, he finds an extremely high ratio: namely, equal quantities of chlorine and ammonia to be most advisable.

Successful protection of the distribution system against infection and the material reduction of "dead-end" complaints by the use of the process has been almost universal. Almost every plant reporting the use for the protection of the distribution system, made reference to the improved condition of the water in "dead-ends."

The stagnation of water in the low velocity sections of distribution systems is undoubtedly of great importance. Pipe slime, tubercula-

TABLE 1—*The ammonia-chlorine process—table showing comparable features of application in twenty widely separated plants*

TABLE 1—*The ammonia-chlorine process—table showing comparable features of application in twenty widely separated plants*

Plant number	Purpose used: Taste odor: Blanketing raw water causes	Purpose used: Taste odor: Prevention of by sludge or algae in plant	Purpose used: Taste odor: Prevention of in distribution system	Purpose used: Sterilization: Only sterilization used	Purpose used: Sterilization: Distribution protection	Point of application: Raw water	Point of application: With coagulant	Point of application: After coagulation	Point of application: After filtration	Source of ammonia: Anhydrous	Source of ammonia: By product sulphate	Source of ammonia: Synethic sulphate	Source of ammonia: Aqua	Delivered price ammonia (NH_3 basis) cts. per pound	Quantities used pounds per million gallons: Ammonia: Maximum	Ammonia: Average	Chlorine*: Maximum	Chlorine*: Average	Ratio—ammonia to chlorine: Maximum	Normal	Average	Practical residual control point and value in p.p.m.		Maximum residual at customer no complaint p.p.m.
1			x	x	x	x				x				10.5		2.5		10		1:4		15 minutes after	0.20	x
2			x		x				x	x				14.9	3.2	2.0	8.4	6.1	1:2	1:3	1:6	Plant effluent	0.30	0.6
3		x	x	x	x		x						x	15.3	1.4	0.9	4.5	2.8	1:1.3	1:3.2	1:4	On filters	0.25	0.4?
4		x		x			x					x		4.9	2.0	1.5	6.0	6.0	1:3	1:4	1:10	End of mixing	0.40	0.5
5	Special			Special		Inlet reservoir				x				10.5	4.0	3.9	4.0	3.9	1:1	1:1	1:1	Reservoir (out)	0.10	0.15
6				x	x		x			x				16.5	2.5	1.3	9.8	5.4	1:3	1:4	1:4	Plant effluent	0.25	0.3?
7	x		x		x				x	x				17.0	3.0	1.5	9.0	4.5	1:2	1:3	1:4	Pumps	0.20	0.3
8				x	x	x				x				10.5	0.8	0.5	3.5	2.3		1:4		7.5 minutes after	0.30	x
9	x			x	x			x			x			6.0	1.6	1.5	5.8	4.9		1:3		Plant effluent	0.50	x
10	x	x	x		x	x†			x	x				15.0	1.0	0.7	3.4	2.4	1:3	1:3.3	1:3.4	Plant effluent	0.25	0.55
															1.0	1.0	3.0	2.6						
11				x	x					x				10.5	0.7	0.6	5.0	3.0	1:4	1:5	1:7	7.5 minutes after	0.30	x
12		x	x		x	x				x				15.0	1.0	1.0	2.8	2.8		1:2		City	0.20	0.40
13		x			x				x	x				15.5	3.0		6.0			1:2		Plant effluent	0.20	x
14			x		x				x	x				20.0	16.6	5.8	41.5	20.7	1:2.5	1:3.5	1:4	Plant effluent	1.00	0.9
15	x			x					x	x				19.0	2.0	2.0	Q.S. resid.					Plant effluent	0.50	0.8
16			x	x	x	x‡		x§		x				18.0	2.5	1.7	10	7.0	1:4	1:4.5	1:5	Plant effluent	0.40	0.5**
17	x	x	x		x		x		x‖		x			6.0	2.3	1.8	9.0	7.0	1:4	1:4	1:4	Plant effluent	0.30	0.4††
															1.3	0.6	5.0	2.5						
18			x	x	x				x	x				24.0	1	0.8	3.5	2.4	1:0.5	1:3	1:3	Plant effluent		0.1
19	x	x		x	x			x			x			6.2	1.7	0.4	2.5	1.3	1:1.5	1:2.3	1:4.5	Plant effluent	0.16	0.2
20			x		x				x	x				16.5	2.0	1.4	5.9	3.7	1:2.0	1:2.8	1:4.3	Plant effluent	0.6	0.5

* Used with ammonia for chloramines—other use not included. † Seven months only. ‡ Summer § Winter. ‖ Eight months.
** "Must be reduced to 0.2 if excess NH_3 is reduced." †† When water temperature is above 55° increased to 0.5 to 0.55.

tion, bacterial growths of acid producing strains, are cumulative in both degree and effect. The oxygen content of the water in such sections becomes less and less with consequent rapid increase in the corrosiveness of the water. Awful tastes and odors are reported present in these sections, being due not only to dissolved iron, but also to products associated with decomposition.

Where the movement is more sluggish, further depreciation occurs and the further problem of red and even black waters result.

The lessening and often the elimination of these causes and effects by the presence of the available chlorine made possible by the ammonia chlorine process is most favorably reported.

Chloramines have been found very effective in ridding filter beds of the objectionable growths which so frequently cause serious troubles. In Richmond, where it was impossible to apply sufficient chlorine for this purpose, chloramines are effectively used when needed. When used periodically the filter should be removed from service and its effluent wasted during cleaning with chloramine application, because intense tastes and odors are generally produced as a result.

SOURCE OF AMMONIA

The ammonia for the process is reported as being obtained in the anhydrous compressed gas in cylinders, by-product coke oven sulphate, synthetic atmospheric sulphate and aqua ammonia. The anhydrous gas is the supply reported at 17 plants, by-product sulphate at 6, synthetic sulphate at one and one reports the use of the aqua ammonia. The evident advantages of the ease of handling and the chemical purity of the anhydrous gas accounts for its greater popularity in spite of its greater cost.

The average delivered price, January 1, 1934, of the anhydrous gas was 15.8 cents per pound as compared with an average of 7.33 cents per pound for the other sources, these prices being on the available NH_3 basis.

Specifications of the by-product coke oven sulphate are necessarily more elaborate and a careful check is required to prevent the highly objectionable pyridine and intolerable cyanide that may be present. Specifications usually limit the former to 0.05 percent and prohibit the presence of any cyanide. The atmospheric or synthetic ammonia sulphate is usually almost chemically pure and is now available in many localities. Some difficulty has been encountered from the

hygroscopic nature of ammonium sulphate and from its corrosive tendency in the dry feed apparatus, although neither seems of sufficient importance to cause serious objections to its use.

The average quantity of ammonia as NH_3 used is found from these reports to be 1.8 pounds per million gallons. Hence, with the use of the higher priced anhydrous supply the average delivered cost of the chemical used is 28.4 cents per million gallons and 13.2 cents when the cheaper grades are used.

AMMONIA CHLORINE RATIO

The chemistry of the ammonia chlorine process applied to water purification is quite involved. Theoretically, the mono-chlorine NH_2Cl, the dichloramine $NHCl_2$, ammonium chloride NH_4Cl_2 or nitrogen trichloride NCl_3 may be formed. However, the mono and the dichloramines are the only two of these compounds that are of interest to the water purification profession. But little is known by even the research chemists of the actual characteristics of the two useful chloramines, both being rather difficult to isolate and are unstable. Consequently, it follows, that in practice the quantity of ammonia and chlorine used is that found to be necessary to give the desired residual at the point selected for control or that found most effective in taste prevention. All who use the process for sterilization use the customer's tap as the real point of control of the residual; but for convenience, the plant effluent is used for regulating the quantity required to give the desired residual at customer's premises. The ratio of the quantities of each depends upon the purpose for which the process is used. When used to prevent chloro-phenolic tastes or odors, usually a larger quantity of ammonia in proportion to the chlorine is used than when the protection of the distribution system is the main objective. In the latter case, the ratio is adjusted to that found to give the maximum persistence. Usually both the quantity as well as the ratio are varied with the water quality and temperature. From the reports received, one pound of ammonia to three pounds of chlorine is shown to be the yearly average.

MAXIMUM RESIDUAL

An effort was made to determine the maximum residual that may be maintained at the consumer's premises in the different supplies without chlorinous taste being produced. In only two cases was more than 0.5 p.p.m. reported as permissible; 0.5 p.p.m. being quite

general and as little as 0.1 to 0.2 p.p.m. the maximum at three localities. There are evidently two factors that influence this important threshold; the condition of the distribution system and the water temperature. It is certain that when distribution systems have become foul with deposits or growths, if these be exposed to the chloramines, severe tastes and odors will be produced in the early stages of application. This condition was so pronounced in Richmond that the only way in which the process could be adopted was to increase the persistence by extremely small increments; two months' time being required before reaching the desired residual. But once attained, no further trouble has resulted. The temperature of the water and probably the organic content, also, has its effect upon the tolerable limit. Reports advise that at very low temperatures a "snow-water" taste is present, which in itself is chlorinous in quality. This is indeed a factor, being difficult to remove, and of course reduces the actual residual that may be used because, being of the same quality, it is cumulative in effect. Another probable effect of low temperatures is the actual increase in residual at the consumer's tap, in spite of the orthotodine indicated quantity remaining constant. Standard practice seems to compare the sample under test a fixed time, usually five or ten minutes after the addition of the orthotolodine, with no correction for temperature. Confirming what has since been found to have been reported by Enslow and others, tests indicate that the orthotolodine indication may be grossly inaccurate at very low temperatures. As an example of the error that may be obtained, treated water samples were taken simultaneously, orthotolodine added immediately and one kept at 1°C. for twenty minutes indicated a residual of 0.3 p.p.m.; the other, warmed in a bath to 20°C. indicated a residual of 0.65 p.p.m. in five minutes. The latter quantity checked closely with the amount that theoretically was present. This perhaps accounts for the many reports of reduced residuals being necessary in winter.

CONCLUSIONS

1. As a means of eliminating tastes and odors caused by the condition of the untreated supply water, the effectiveness of the process is quite limited.

2. As a means of *preventing* the formation of tastes and odors in the stagnant sections of the distribution systems, it is almost universally successful.

3. The process proves to be of real assistance in the reduction of "dead-end" red water complaints.

4. For prolonged sterilization, it is much more practical than chlorine alone.

5. As an emergency cleanser for filter beds when infested with organic growths, it is successful where chlorine alone is ineffectual.

6. The most used ratio of ammonia to chlorine is one pound of ammonia to three pounds of chlorine.

7. The most used source is the anhydrous gas compressed in cylinders.

8. Except where used to prevent tastes and odors being formed or increased during the process of purification, prechlorination without ammonia is becoming more generally used and the formation of the chloramines is accomplished after filtration.

9. While a greater chlorine residual, when in the form of the chloramines, may be used without causing objectionable chlorinous tastes than with chlorine alone, there is a quite definite upper limit which may not be exceeded without tastes resulting. The quantitative limit will often vary with variations in the condition of the water.

10. The orthotolodine indicated chlorine residual, especially at very low temperatures, is apt to be much less accurate with the chloramines than when chlorine alone is indicated.

11. Practically no injurious effects are reported and, on the other hand, now that its limitations and uses are better understood, the process is firmly established in the practice of water purification.

The author regrets that no one of the plants reporting mentioned certain features or results of the ammonia-chlorine process which are of importance.

As previously stated, the reports indicate that when the cause of the taste and odor is other than an apparently limited class of compounds, the process is virtually useless as a means of *elimination*. While that is true, there are probably a large number of supplies, which, having no filters, cannot obtain the benefit of the carbons for taste/odor elimination. Many of these experimenting with the ammonia-chlorine process expected taste/odor *elimination* and, failing to obtain *elimination*, believed the process to be of no value in taste and odor control. It is felt that many supplies of the class under discussion would find that while falling short of *elimination*, the process would provide a *reduction* of sufficient degree to more than justify its adoption.

Again there are many small supplies that present a real problem in sterilization, due to the wide daily variation in quantity of water demand.

Automatic chlorinators are expensive and perhaps will always be comparatively difficult to keep in efficient condition. By being able to use much higher residuals without offensive chlorinous tastes when using the ammonia-chlorine process, these supplies are able to so adjust the treatment as to assure safety at maximum draught, and yet not cause intolerable chlorinous tastes during low draught periods.

THE EFFICIENCY OF THE AMMONIA-CHLORINE PROCESS

By A. E. Griffin

(Sanitary Engineer, Wallace and Tiernan Company, Inc., Newark, N. J.)

The study of the efficiency of chloramines herein reported was undertaken in the hope that some general ratio between the killing speed of definite residual chlorine values as chlorine and chloramine within definite time intervals might be obtained. The results of these tests coupled with reports from various plant operators indicate in general that chloramine residuals two times stronger than chlorine residuals may be expected to accomplish the same bacterial kill within the same period of contact. For instance, where it has been found that 0.20 p.p.m. residual chlorine is adequate after a fifteen minute contact, 0.40 p.p.m. residual chlorine where ammonia and chlorine is used may be expected to accomplish the same result in the same length of time. Furthermore, these studies showed that fully 99 percent of the B. coli in average waters are killed with relatively small residuals of chlorine, either as chlorine alone or as chloramine, and that it becomes necessary to carry residuals of higher values in order to eliminate this final 1 percent. This initial killing power becomes very important when it is realized, according to Tonney, Greer and Danforth (1), that the pathogenic organisms are much less resistent to chlorine than B. Coli.

Cognizant of the fact that nitrogen trichloride (NCl_3) (2) is formed below pH 4.4, dichloramine ($NHCl_2$) at pH 4.4, a mixture of di- and mono-chloramine between 4.4 and 8.5,with mono-chloramine (NH_2Cl) exclusively above pH 8.5 three plants of wide pH ranges were selected for the experiments. New Brunswick, N. J., with a pH normally from 5.5 to 6.5 was picked for the acid water, the Bound Brook, N. J., plant of the Elizabethtown Water Company for an example of neutral or near neutral water, and Allentown, Pa. for the alkaline range, in this case averaging from pH 7.5 to pH 7.8.

Within the limits of the three laboratories the same analytical technique was followed at each plant. Wallace & Tiernan chlorine

and ammonia apparatus was used in all instances while water flow rates were taken from the operating records. The time interval between ammonia and chlorine applications was measured at Allentown by applying clay to the water and timing its appearance at the sampling points, while at New Brunswick and Bound Brook the contact times were calculated from pump ratings and pipe sizes. In all cases ammonia was applied first. At Allentown the ratio of chlorine to ammonia averaged 3:1, at Bound Brook 4:1 and at New Brunswick from 3:1 to 5:1. The maximum color developed with O.T. was taken as the correct residual chlorine reading. The end of the various time periods was controlled by adding sterilized sodium thiosulphate to the sample under consideration in sufficient quantities to destroy any chlorine present. B. Coli was determined by streaking cultures of those lactose broth tubes showing gas on eosin methylene blue agar plates. Doubtful colonies on these plates were further confirmed in lactose broth, brilliant green bile and Krumwiede Media.

The most complete data were obtained at Allentown where facilities allowed the most intensive work. Analyses were started here early in January and continued into April, 1934. In all, some eighty samples were collected from which innoculations for fermentation and plates for total counts at 37.5°C. were made. The following tables are based on the results of these examinations. All bacterial results reported are the averages of at least two tests for the given time interval and residual chlorine content.

Table 1 shows the effect of chlorine alone on the Allentown, Pa., water as pumped from the creek.

The data in table 1 show a gradual elimination of B. Coli with increasing amounts of residual chlorine, until 0.50 p.p.m. is obtained, where all are killed within fifteen minutes.

In table 2, where chloramines have been used, the same gradual elimination of B. Coli is shown, requiring in this case 0.80 p.p.m. chlorine to kill them entirely in 15 minutes and half that or 0.40 p.p.m. to do the same trick in 2 hours.

These tables indicate that it requires 0.80 p.p.m. residual chlorine as chloramine or 0.50 p.p.m. as chlorine to entirely eliminate B. Coli from the Allentown raw water within 15 minutes where the pH averages 7.6 and the temperature 55°F. However, if two hours contact were allowed 0.40 p.p.m. would accomplish the same amount of work as 0.35 p.p.m. chlorine alone. Gerstein (3) and Race (4) in

fact have shown that when equivalent quantities of chlorine as chloramine are added to a water containing B. Coli the ultimate killing power of the chloramine is greater than chlorine alone.

TABLE 1

Allentown, Penna.—Effect of various dosages of chlorine on B. Coli content of raw water. Average of 35 analyses

B. Coli per 100 cc. raw water: Maximum, 10,000; minimum, 100; average, 1900

RES. Cl END OF 15 MINUTE CONTACT, P.P.M.	B. COLI PER 100 CC. Minutes contact chlorine with water					pH AVERAGE
	15	30	45	60	120	
0.15	7.5	5.5	3	1	0.05	7.6
0.20	3.5	3.5	1.4	2.1	0.03	
0.25	5	2	2	0	0	
0.30	3	1.3	1.5	0.8	0.03	
0.35	0	0	0.6	0	0	
0.40	3	2.7	0.5	0.23	0	
0.50	0	0	0	0	0	
0.60	0	0	0	0	0	

TABLE 2

Allentown, Penna.—Effect of various dosages of chloramine on B. Coli content of raw water. Average of 45 samples

B. Coli per 100 cc. raw water: Average, 1900. $Cl:NH_3$, 3:1

RES. Cl END OF 15 MINUTE CONTACT, P.P.M.	B. COLI PER 100 CC. Minutes contact chloramine with water					pH AVERAGE
	15	30	45	60	120	
0.15	10	8	6	6	2	7.6
0.20	7	6	6.5	6	3	
0.25	4	7	8	—	1	
0.30	10	6	6	2	0	
0.35	2.3	3	3.3	1	0.25	
0.40	4.6	2	0.3	2.6	0	
0.50	3	0	—	—	—	
0.60	2.4	0.9	0	0	0	
0.80	0	0	0	0	0	

The B. Coli load of the raw water varied from 100 to 10,000 per cc. from day to day, and even from hour to hour. Since it was obviously impossible to time the collection of the raw water sample close

enough to be sure it was exactly representative of the water at the moment of chlorination the B. Coli index per 100 cc. of all the raw water samples was averaged. This gave a figure of 1900 B. Coli per 100 cc. and is believed to be a fair index of the bacterial quality of the raw water. A residual chlorine content as chloramine of but 0.15 p.p.m. killed 99.48 percent of the B. Coli within 15 minutes and it required 0.80 p.p.m. residual to kill this remaining 0.52 percent within the same period. A residual chlorine as chlorine alone of 0.15 p.p.m. killed 99.61 percent of the B. Coli within the same time period, but it required a residual of 0.50 p.p.m. to kill the remaining 0.39 percent within 15 minutes. This has been recognized before because Gerstein (2) in 1930 reported that 0.4 p.p.m. Cl_2 and 0.1 p.p.m. NH_3 removed 99 percent of the B. Coli in 0.2 of an hour.

TABLE 3

Allentown, Penna.

	RAW	AVERAGE TOTAL BACTERIA PER CUBIC CENTIMETER AT 37.5°C.				
		Contact with chlorine or chloramine, minutes				
		15	30	45	60	120
Chlorinated	490	35	36	44	39	37
$Cl_2 + NH_3$	270	40	35	38	38	37

Further data show that 0.40 p.p.m. chloramine residual will kill 100 percent of the B. Coli in 2 hours but that 0.80 p.p.m. will accomplish the same result in 15 minutes. Contrast this with chlorine alone, where 0.35 p.p.m. effects a 100 percent kill in two hours or 0.50 p.p.m. in 15 minutes.

In all of these experiments it has been noted that the reduction of total water bacteria growing at 37.5°C. is practically all done within the first 15 minutes. At New Brunswick where we used 5 minute intervals it was found that the bacteria growing on agar at 37.5°C. were not further reduced after the first 5 minutes contact with chlorine or chloramine.

Table 3 is an average of all the total bacterial counts on agar at 37.5°C. after 24 hours. The counts on the individual samples never varied far from these results. It is worth mentioning that the bacteria were reduced to very close to the averages reported in this table, irrespective of the total amounts of chlorine added or the

residual chlorine as chlorine alone or chloramine after a 15 minute contact.

While these experiments were being conducted it became the exception at the Allentown Plant, rather than the rule, to find B. Coli on top of the filters as determined in the course of routine operation.

At Bound Brook, N. J., ammonia and chlorine are regularly added

TABLE 4

Bound Brook, N. J.—Five-minute chlorine demand with varying doses of chlorine (results in p.p.m.)

Chlorine applied	0.80	1.00	1.20	1.40
Res. Cl after 5 minute contact	0.15	0.16	0.19	0.31
5 minute chlorine demand	0.65	0.84	1.01	1.09

TABLE 5

Bound Brook, N. J., Millstone River—Effect of various dosages of chloramines in B. Coli content of raw water 1:4 ratio

B. Coli per 100 cc. raw water: Average, 1600

RES. Cl AT END OF 15 MINUTE CONTACT	B. COLI LEFT PER 100 CC.						
	Minutes contact chloramine with water						
	5	15	30	45	60	120	180
0.35	3	3	3	2	0	0	0
0.38	8	6	6	4	2	0	0
0.42	2	4	0	0	0	0	0
0.43	4	2	2	0	0	0	0
0.60	0	0	0	0	0	0	0
Chlorine alone							
0.30	1	1	1	0	0	0	0
0.38	0	0	0	0	0	0	0

to the water at the low lift pumping station, in quantities sufficient to maintain residuals of 0.30 p.p.m. on top of the filters.

The chlorine demand of this water is quite high, varying with the amount of chlorine added. Table 4 shows the extent of this demand.

In plant practice residuals up to 0.40 p.p.m. are sometimes obtained when low turbidities and color prevail. However, these residuals quickly dissipate unless ammonia is used to preserve them. At New Brunswick this is even more marked where it is practically impossible

to maintain a residual in the subsidence basin a time distance of 45 minutes from the low lift pumps with chlorine alone, whereas residuals of 0.20 p.p.m. may be easily maintained with the same application of chlorine when ammonia in the ration of 4:1 is used.

Due to the physical layout of the plant it was impossible to collect as much data at this plant as at Allentown, but the few results obtained were very closely in line with those at the latter place. Here 0.43 p.p.m. chloramine removed 99.62 percent of the B. Coli within 15 minutes and 99.37 percent within 5 minutes. While 0.30 p.p.m. chlorine removed 99.96 percent within 5 minutes, 0.60 p.p.m. chloramine removed 100 percent within that time, and 0.38 p.p.m. chlorine removed 100 percent within the same period.

Summarizing the speed of killing at these two plants we have the data in table 6.

TABLE 6

PLACE	pH	RES. Cl REQUIRED AT END OF 15 MINUTE CONTACT TO KILL 100 PERCENT B. COLI IN 15 MINUTES		RATIO OF RES. Cl TO RES. CHLORAMINE TO EFFECT 100 PERCENT KILL WITHIN 15 MINUTES
		As chlorine	As chloramine	
Allentown	7.6	0.50	0.80	1:1.6
Bound Brook	6.9	0.38	0.60	1:1.6

Applying a safety factor of 25 percent for extreme conditions it then appears that chloramine residuals double the strength of chlorine residuals with the same period of contact will accomplish the same amount of work, and at the same time preserve sufficient residual chlorine throughout the system to hold aftergrowths in check, to eliminate the dangers of after pollution and to minimize red water troubles in dead ends. Chloramine residuals also have a tendency to increase the carrying capacity of water systems due to their inhibition of bacterial and algal activities on the inside of the pipes.

At New Brunswick the B. Coli load in the raw water was much lower than in either of the two waters just discussed. The few analysis made on it before they entirely disappeared in February showed that 100 percent of the B. Coli were killed in less than 5 minutes with doses of chlorine or chlorine and ammonia to give a residual

of 0.20 to 0.30 at the end of 5 minutes contact, in a water of pH 5.5 to 6.5.

SUMMARY

No attempt has been made to draw any definite conclusions from these studies, for it is realized that waters react so differently that no one rule can be made for all. The evidence collected, however, does seem to indicate in general that (1) the initial kill of B. Coli with chlorine or chloramine is very high on the average water, 99 percent or better within 15 minutes; (2) at times relatively high residuals as chlorine or chloramine must prevail at the end of a 15 minute contact in order to effect a 100 percent reduction of B. Coli within that time; (3) for a given time of contact chloramine residuals two times greater that chlorine residuals will accomplish approximately the same result; (4) higher residuals are required with alkaline waters than with acid water in order to effect complete elimination of B. Coli.

Before closing I wish to say that the data presented in this paper have been made possible by the coöperation of Mr. Vail of New Brunswick, Mr. Radcliff of Elizabethtown Water Company and Mr. Krum of Allentown, who made the great majority of these analyses.

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CHLORINE AND THE ORTHO-TOLIDINE TEST IN THE PRESENCE OF NITRITE

By Roberts Hulbert

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In view of unlimited faith and reliance generally accorded the result of the ortho-tolidine test for residual chlorine, it is well not to lose sight of the fact that the familiar yellow color developed is not always specific for chlorine, and that correct interpretation of this reaction may well depend upon the recognition and exclusion of interfering substances. The purpose of this discussion is to review briefly the question of interference of nitrite ion, an impurity which is not only very common in natural waters, but also one which is usually formed in ammonia-treated water. It is accompanied frequently by two other familiar nitrogen oxidation products; ammonia, which is one stage lower in the nitrogen cycle; and nitrate, the next higher step. So far, no one seems to have observed that either of the latter interfere with the o-tolidine reaction, and for that reason both are ignored hereafter in this discussion. Nitrites, however, may, and unquestionably do often interfere seriously with the test, and it seems pertinent therefore to consider (1) the mechanism of nitrite formation in water, (2) how and under what conditions it interferes, and (3) ways and means of avoiding this trouble.

BACTERIAL ORIGIN OF NITRITES FORMED IN WATER

Not long ago the three transition forms of nitrogen mentioned, were considered the most valuable indicators of contamination of water by questionable organic matter. Supplanted now by the bacteriological index, these compounds continue to persist, nevertheless, in all surface water and sewage effluents, serving to remind us of the significant chemical changes which may result from biological growth.

Species of bacteria capable of breaking down the complex forms of organic nitrogen into the simpler forms of ammonia, are legion. This process goes on in nature under many different kinds and condi-

tions of environment. On the other hand, the two subsequent stages of nitrification, viz., oxidation of ammonia to nitrite, and the latter in turn to nitrate, are each accomplished by a single, particular genus of soil bacterium, Nitrosomonas (Winogradsky), and Nitrobacter (Winogradsky) respectively. In contract to the ammonifiers, these two organisms grow and develop actively in water only under somewhat restricted environmental conditions; they are both peculiarly selective as regards food for growth, or energy material.

The nitrite-forming organism, Nitrosomonas, requires the presence of inorganic ammonia, or a salt of ammonia, from which it obtains energy in the process of oxidizing it to nitrite. As regards temperatures, the nitrifying bacteria appear to be active in water between the rather wide limits of perhaps 50 to 100 degrees F., with an optimum between 75 and 85 degrees. Furthermore a slightly alkaline reaction is essential to growth, somewhere between pH 7.0 to 8.0. Inorganic bases, such as sodium, calcium or magnesium, must also be present, to neutralize the inhibitive acids which are formed.

Natural surface waters comply with these requirements for growth of the nitrifying bacteria especially well, ordinarily providing a nearly ideal medium; and it is probable that both types are quite invariably present therein, either in a dormant or active state, depending upon conditions. For example, Nitrobacter, the nitrate former, is known to be inactive during the period when ammonia is being oxidized to nitrite by Nitrosomonas, which latter, in turn, becomes dormant when ammonia is exhausted, the subsequent growth of Nitrobacter than proceeding (1).

During the past year, careful investigation has brought out many facts all unmistakably pointing to the biological origin of nitrite formed in filtered water at Detroit, during the summer season when ammonia is being added (2). The recent isolation of Nitrosomonas from both raw and tap water (by the writer's colleague, Mr. Feben) has completed a convincing chain of evidence substantiating this belief. In the opinion of the writer it is a practical certainty that nitrite will be formed, during the summer months, in nearly every water supply treated with ammonia. Once ammonia has been added, one may confidently predict its appearance at some later stage of the process where conditions most favor this form of biological activity. It may happen to be anywhere during the passage of the treated water through filters, clear well, storage tanks or distribution mains. Apparently the usual concentrations of chloramine formed

in water treatment do not greatly retard, and certainly do not altogether prevent nitrification.

The filter plant operating-chemist should know if, when, and where nitrites are occurring in his water supply for two reasons: (1) they give a false yellow color with ortho-tolidine when testing for chlorine by Standard Methods; and (2) in the absence of free ammonia nitrites present an extremely high chlorine demand. These two considerations may be briefly discussed.

Interference with the ortho-tolidine test

There is substantial agreement that very high concentrations of nitrite in water does develop the characteristic chlorine-yellow color with ortho-tolidine. On the other hand, there appears to be some disagreement regarding what amount must be present to produce this reaction.

In their research on the sensitivity of the o-toludine test for free chlorine, Buswell and Boruff (3), say, in their conclusions regarding nitrite interference, that

> Nitrites in low concentrations, as found in potable waters, do not interfere with the o-tolidine test for free chlorine because they are oxidized by the chlorine added . . . the compounds formed have no effect on the o-tolidine reagent . . . nitrites above 1.0 p.p.m. in terms of N do give a slight color with the o-tolidine reagent . . . this color becomes darker with increasing concentrations of the nitrite, then finally fades out . . . in the presence of free chlorine nitrites are oxidized to an extent that they do not interfere.

If it were true, that 1.0 p.p.m. of nitrite nitrogen, or more, must be present to produce a yellow color reaction with o-tolidine, there would be little need for concern over its interference with chlorine, since such a high concentration seldom occurs in natural water, or even ammonia treated water. However, in this respect Buswell and Boruff's conclusions have not been substantiated by other investigators. Their method of investigation consisted of adding a number of different concentrations of nitrite to water containing a fixed concentration of free chlorine, in nearly all cases the nitrite being in excess, or more than sufficient to reduce the chlorine. O-tolidine reagent was then added and the presence or absence of typical chlorine-yellow color observed qualitatively. After partial oxidation by chlorine, considerable nitrite presumably remained in nearly all the dilutions, but their data fail to show how much, if any. Upon this would depend the intensity of color developed, which was recorded

as zero for all tubes except those which contained more than 1.0 p.p.m. of nitrite. Repeating this same experiment the writer obtained positive yellow color in every tube containing an excess of nitrite, from 0.01 p.p.m. nitrite nitrogen on up. In the case of low nitrite concentration a reaction period of approximately 30 minutes is required for color development, and in addition strong light. Also it is important that a fresh, unoxidized solution of nitrite be used. It is just possible one or more of these factors were overlooked by Buswell and Boruff.

More recently, Braidech (5), Berliner and Howe (6), and Hedgepeth (7) have stated that nitrites do yield a typical chlorine-yellow with o-tolidine. Notably, Braidech has published a complete table of nitrite-o-tolidine color development in comparison with chlorine, showing that the color intensity increases with reaction time, and that given sufficient time a very low concentration of nitrite nitrogen will produce an even more intense yellow than an equivalent concentration of chlorine. About 45 minutes are required to produce the maximum color in the case of nitrite nitrogen concentration between 0.01 and 0.05 p.p.m., and approximately 10 to 15 minutes for those between 0.1 and 1.0 p.p.m. In case of the usual nitrite concentrations present in water, 30 minutes exposure in good strong light is sufficient for maximum color development. Similar concentrations of chlorine will reach a maximum after 5 to 10 minutes reaction. For all practical purposes one may say that any given concentration of nitrite nitrogen will yield, after 30 minutes reaction time with o-tolidine in daylight, the same depth of color as would an equivalent concentration of chlorine after 5 to 10 minutes exposure. It appears, then, that light and a long reaction period are essential to the full development of nitrite-o-tolidine color; in the case of chlorine, light is unnecessary and the time element much less. Temperature seems to affect both reactions about the same.

Due to the current practice of ammoniation, nitrite and chloramine are now frequently both present in the same water. We may inquire as to just what happens when o-tolidine is added to such a mixture. Give normal daylight exposure and the ordinary nitrite and chloramine concentration, the yellow due to chloramine will develop in the tube first, reach its maximum in 5 to 10 minutes and thereafter begin to fade rather rapidly; the nitrite yellow will begin to appear in about 10 minutes, reach its maximum in about 30 minutes, and then also begin to fade slowly. In this case, and providing one follows direc-

tions in Standard Methods and waits 30 minutes before observing color, it is probable that the reading then obtained will be that due exclusively to nitrite, and not chloramine. On the other hand, the 5 to 10 minute reading will be practically that of chloramine only, providing the concentration of nitrite in the solution is not abnormally high. Experience at Detroit has led the writer to believe that the change from 5 minutes contact (after adding o-tolidine, and before observing color) specified in the 1925 edition of Standard Methods, to 30 minutes required by the 1933 edition, was particularly unfortunate. It appears likely that slow-forming nitrite color was attributed to chloramine, and the change made unadvisedly.

The method used at Detroit during the summer months for avoiding nitrite interference takes advantage of the fact that interfering nitrite color does not develop in the dark, unless the concentration be abnormally high. On the other hand, chloramine-yellow develops equally well in either light or darkness. When both are present, the comparator tube is placed in a dark-cabinet, o-tolidine added, and the tube left in the dark for 15 minutes. At the end of this period it is removed to the rack and the chloramine color matched in the light as quickly as possible. No reason to suspect misleading results has become evident in our experience with this technique, and it appears to be sound and worthy of more widespread use.

Berliner (6), Braidech (5) and Hedgepeth (7), recommend preliminary oxidation of nitrite with hydrogen peroxide in acid solution to prevent its possible interference with the o-tolidine test. In using this procedure, the writer has found that considerably more than the specified 0.5 cc. of H_2O_2 must be used ordinarily to accomplish complete oxidation of nitrite to nitrate. If sufficient peroxide is used to accomplish this, the chloramine is usually partially, and sometimes completely dissipated as well. The addition of any other chemical to the Nessler tube containing chlorine in water solution is always open to question, since the substance added might oxidize o-tolidine and produce the characteristic yellow; this color reaction, of course, not being specific for chlorine except in the absence of other oxidizing agents (4).

Braidech (5) has reported that nitrite interference with chloramine-o-tolidine color is "very materially reduced when free ammonia is found to be present." In the writers hands, solutions of nitrite, chloramine, and excess ammonia have repeatedly shown the full nitrite color development, with no retarding effect manifest in the presence of free ammonia.

Chlorine demand for nitrite oxidation

In the absence of ammonia, nitrite is oxidized by free chlorine almost instantaneously, providing the latter is in considerable excess. Under these conditions it is well to take note of the fact that one part of nitrite nitrogen may require from 8 to 10 times its own weight of chlorine for oxidation. It is quite possible for the ordinary dose of chlorine, applied for bactericidal purposes, to be completely consumed by a relatively small concentration of nitrite; and if nitrite remains, this may be easily mistaken for residual chlorine by the Standard Methods test.

If free ammonia is also present in the water, only about one-third of the chlorine added will react with nitrite, and the remaining chlorine and unoxidized nitrite may co-exist in the water for several days without further apparent reaction. This, at least, is true in the case of laboratory experiments. In actual practice, during the warm-water months, it appears that free ammonia in solution may become converted rapidly over to nitrite, while the treated water is passing through the system, residual chlorine disappearing in the process. Braidech (5) also reports this fact (without reference to its seasonal nature) and further states that in laboratory bottles there is no appreciable loss of ammonia to nitrite. Since nitrifying bacteria do not flourish in laboratory flasks exposed to light and without aeration and suitable high temperature incubation, it seems this discrepancy between laboratory and field observations is explainable.

In conclusion, it seems reasonable to inquire how far one is justified in dosing ammonia during the summer months, to form nitrite, which in turn may rapidly deplete a chlorine residual. To a considerable extent, the answer will depend on how certain one is, exactly where, how much, and under what conditions nitrite is being formed, and with what certainty it is distinguished from residual chlorine by the o-tolidine test.

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THE DETERMINATION OF FREE CHLORINE

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A number of reagents have been proposed for determination of free chlorine or chloramine in water. Phelps suggested the use of o-tolidine in acetic acid (1) and Ellms and Hauser devised a method for estimation of chlorine based upon the use of o-tolidine in hydrochloric acid (2). The starch iodide test has been used for some time by certain workers. More recent suggestions are the use of dimethyl-p-phenylenediamine hydrochloride as a reagent for chlorine (3) and methyl orange for the estimation of chlorine in the absence of chloramine.

The chief interfering substances in the accurate determination of chlorine by o-tolidine have been found to be manganese, nitrites and iron (1, 5, 6, 7, 8). At an earlier date Boruff and Buswell showed that there was no interference from nitrites and iron under the conditions necessary for making the o-tolidine test for free chlorine (9). But with the present general use of chloramine instead of chlorine longer reaction time must be allowed for the development of full color. Where this long reaction time is used, nitrites and iron, as well as manganese, interfere in the test. Obviously, the o-tolidine reagent is not entirely satisfactory and attempts have been made to adapt the reagent to the purpose by making corrections or eliminating the cause of interference either mechanically or chemically (4).

In the o-tolidine test, each of the following would exert an effect: concentration of chlorine, oxidation potential of the chlorine or chloramine, pH and HCl concentration, concentrations of manganese and iron and the degree of oxidation of each, concentration of nitrite, concentration of the reagent and reaction time. With these things in mind work has been carried on in an attempt to find a reagent which would eliminate part of the difficulties experienced with o-tolidine. This investigation has been divided into three parts, involving (I) the application of the principle of oxidation-reduction potentials to the problem (II) nitrite interference in the o-tolidine test and (III) the nature of o-tolidine reactions.

I. APPLICATION OF THE PRINCIPLE OF OXIDATION-REDUCTION POTENTIALS TO THE PROBLEM

Conant and Fieser (10) have shown that the reduction potentials of various quinones are functions of their structure. From this it seemed possible that certain reduced compounds which give the quinonoid structure upon oxidation might be investigated and a system selected which would have such potential that it would be oxidized by chlorine or chloramine, but would not be affected by some of the substances interfering in the present o-tolidine test. The oxidation-reduction potentials of various systems involved are given in table 1. E_0 is the "normal potential" at pH = 0 (referred to the system $H^+ \rightarrow H^0 = 0$) and E is the potential at another definite pH value (11). In each case the oxidized form in the system has been placed on the left and the reduced form on the right so that all E_0 values are positive.

In this connection, it should be noted that Clark, Cohen, and Gibbs (11) determined the potentials of certain organic meriquinone-amine systems to be as follows:

System of	E_0 *(volts)*
o-tolidine	+0.873
benzidine	0.921
p-aminodimethylaniline	0.751

Experimental

As stated above, an attempt was made to apply the principle of variations in oxidation-reduction potentials of various oxidant and indicator systems to the problem of determining free chlorine colorimetrically. For this purpose, there were obtained or synthesized in this laboratory pure reduced quinones or compounds which upon oxidation would give the quinonoid structure and hence, color. Fifty compounds were investigated. Of each compound tested, 0.5 gram was weighed out and dissolved in 400 cc. of distilled water. Substances insoluble in water were treated with sufficient HCl or NaOH to convert them to the soluble salt form and were then made up to volume with distilled water. Of the solution of the reagent 1 cc. was added to the sample in a 50 cc. Nessler tube in all tests except where other volumes are specified.

The chlorine solution used was made up from bleaching powder, sodium hypochlorite, or as was found better, from chlorine produced in a small generator by reacting MnO_2 and HCl. Chlorine water was

added to ammonia free water and allowed to stand until the chlorine demand was satisfied. Where chloramine was desired, the calculated amount of NH_3 was added and the solution allowed to stand 45 minutes. The usual o-tolidine test was then applied to check the chlorine concentration. The compounds used were tested also with chlorinated tap water. The effects of manganese, nitrites, iron, pH and acid concentration were investigated.

Five series of compounds were investigated, these being derivatives of benzene, naphthalene, anthracene, benzidine and miscellaneous compounds. The compounds and results obtained with each series follow.

Derivatives of Benzene

Compounds investigated:

(1) hydroquinone
(2) p-ethoxyphenol
(3) p-aminophenol
(4) o-aminophenol
(5) p-monomethylaminophenol
(6) o-monomethylaminophenol sulfate
(7) p-dimethylaminophenol hydrochloride
(8) p-dimethylaminophenol sulfate
(9) o-dimethylaminophenol
(10) m-dimethylaminophenol
(11) aniline
(12) dimethylaniline
(13) m-nitrodimethylaniline
(14) p-phenylenediamine
(15) p-aminodimethylaniline sulfate
(16) o-toluidine
(17) 2,4-diaminotoluene sulfate
(18) 2,4-diaminoanisole
(19) o-aminobenzenesulfonic acid
(20) 3,5-dihydroxy-4-nitrotoluene
(21) p-aminoacetophenone
(22) w-diethylamino-3,4-dihydroxyacetophenone
(23) phenylurea

The results obtained with the compounds of the benzene series showed them to be considerably inferior to o-tolidine as a chlorine reagent. They were not sensitive enough in acid solution, were too easily oxidized in alkaline solution by air, and some were oxidized by iron.

Compounds numbers 6, 7, 8, 15, and 18 gave better results than the others listed in the above series. Of these number 15, i.e., p-aminodimethylaniline or dimethyl-p-phenylenediamine has been used in the form of the hydrochloride by some workers (3). In this laboratory ferric iron was found to oxidize the compound as indicated in the foregoing table of oxidation-reduction potentials.

Derivatives of Naphthalene

(24) 1-naphthylamine-3,6,8-trisulfonic acid
(25) 2-naphthylamine-6,8-disulfonic acid (amino G acid)
(26) 2-naphthylamine-5,7-disulfonic acid (amino J acid)
(27) 2-amino-8-naphthol-6-sulfonic acid
(28) 1-amino-8-naphthol-3,6-disulfonic acid (H acid)
(29) 2-amino-3,6-disulfonic acid (amido R acid)
(30) aminoquinoline (not strictly a derivative of naphthalene)

In general, the production of color by the action of chlorine with derivatives of naphthalene was somewhat better than that produced with derivatives of benzene. The compounds studied were more stable in solution and were more resistant to oxidation by dissolved oxygen than the derivatives of benzene. The presence of amino and hydroxyl groups in the 1,8 or 2,8 position seemed to be necessary for production of a satisfactory color and the presence of the sulfonic acid group appeared to intensify the color. The chief objections to use of these compounds as chlorine reagents were that (1) manganese interfered, (2) nitrite interfered, and (3) color was fugitive in some cases.

Best results in the above series were obtained with two compounds: (27) 2-amino-8-naphthol-6-sulfonic acid produced a good yellow color in acid solution with chlorinated tap water and a deep red color when the chlorine concentration was increased. Both oxidized manganese and nitrite produced color with the compound in acid solution. The alkaline solution of the compound darkened on standing for 72 hours. (28) H acid or 1-amino-8-naphthol-3,6-disulfonic acid produced in tap water a greenish yellow color in acid and reddish brown color in alkaline solution. Color faded after a short time. Manganese and nitrite both produced color with the compound in acid solution.

Derivatives of Anthracene

Compounds investigated:

(31) alpha-aminoanthraquinone
(32) anthraquinone and diphenylanthranol
(33) 2,4-diphenylhydroquinone

In general, compounds of this type are very insoluble in water and give only feeble colors with chlorine as would be expected. They were therefore eliminated from further consideration.

Derivatives of Benzidine

Compounds investigated:

(34) benzidine
(35) 3,3′-dimethylbenzidine (o-tolidine)
(36) 3,3′-diethylbenzidine
(37) 3,3′-dichlorobenzidine
(38) 3,3′-benzidinedisulfonic acid
(39) 3-benzidinemonosulfonic acid
(40) 2,2′-benzidinedisulfonic acid
(41) 2,2′-dinitrobenzidine
(42) 3,3′-dimethyl-5,5′-dinitrobenzidine
(43) diphenylbenzidine

Five of the above compounds (numbers 36, 37, 40, 41, and 43) were not available and were therefore synthesized and purified in this laboratory.

Conant and Fieser have shown that substitution of alkyl, phenylene, or hydroxyl groups lowers the reduction potential of quinone and that halogen, carboxyl, and sulfonic acid groups raise the reduction potential (10). Therefore an attempt was made to improve upon the o-tolidine reagent by substitution of various groups in the benzidine nucleus. By this means it was thought possible to increase sensitivity to chlorine while eliminating interference from other substances. The detailed results obtained with the various compounds follow:

(34) Benzidine. This compound is not as sensitive to chlorine as o-tolidine. Manganese interfers considerably, giving a permanent yellow color.

(35) 3,3′-dimethylbenzidine (o-tolidine). Some of the limitations of this compound have been mentioned. Nitrite interference is discussed later in this paper.

(36) 3,3′-diethylbenzidine. Replacement of the methyl groups of o-tolidine by ethyl gives a compound which is very similar in its action to o-tolidine in all respects.

(37) 3,3′-dichlorobenzidine. This compound gave color with chlorine varying from green to blue. The color was not permanent but faded after a few minutes. A modification of the standard procedure to addition of 1 drop instead of 1 cc. of reagent gave a color lasting for 20 minutes.

With oxidized manganese the compound gave a fleeting blue color which changed to green when HCl was added. As little as 0.04 p.p.m. of nitrite-nitrogen produced a yellow color which deepened to

orange with increasing nitrite concentration. The compound gave no color with 2.0 p.p.m. ferric iron in 45 minutes.

(38) 3,3′-benzidinedisulfonic acid. This compound reacted in a very similar manner to (37) with chlorine and chloramine. When more HCl was added the color changed to yellow and then faded out entirely.

With manganese a green color was produced which lasted 10 minutes, but faded rapidly to pink when excess HCl was added. The compound is apparently more sensitive to nitrite than o-tolidine. As little as 0.03 p.p.m. of nitrite-nitrogen was found to give a yellow color which deepened to orange with increasing nitrite concentration. Ferric iron (2.0 p.p.m.) produced no color in 45 minutes.

(39) 3-benzidinemonosulfonic acid. Elimination of one of the sulfonic acid groups from the disulfonic acid was found to be of little benefit. The results obtained were similar to those with the disulfonic acid, but the colors produced were of a more dusky hue and lacked the brilliance and intensity obtained with the disulfonic acid.

(40) 2,2′-benzidinedisulfonic acid. It was thought that shifting the sulfonic acid groups to a different position in the molecule might change the potential sufficiently to correct the difficulties with the 3,3′ compound. The results were disappointing. Only a pale yellow was produced with strong chlorine solution.

(41) 2,2′-dinitrobenzidine. The solution of this compound was of such intense yellow color that 1 cc. gave considerable color to 50 cc. of distilled water and the color was only slightly deepened by chlorine. The chlorine color apparently was not deepened by action of oxidized manganese.

(42) 3,3′-dimethyl 5,5′-dinitrobenzidine. Substitution of two hydrogens on o-tolidine by nitro groups was found to give a reagent the solution of which was highly colored. A deep yellow color was produced in chlorinated tap water, but the color of the reagent interfered with the color produced by action of chlorine.

(43) Diphenylbenzidine. It was thought that substitution of one hydrogen of each amino group by a phenyl might give a satisfactory reagent. The resulting compound was too insoluble for practical work.

A comparison with the results obtained with the other four series shows the benzidine series to be the best of those investigated. Throughout the benzidine series color is produced in acid, but not in alkaline solution. Ortho-tolidine was found superior as a chlorine

reagent to the other compounds studied. Compounds with which there was no interference from manganese and nitrite produced only fleeting or temporary colors with chlorine and chloramine.

Miscellaneous

(44) tetramethyldiaminodiphenylmethane
(45) p,p′-diacetyldiaminodiphenylmethane
(46) 3,3′, 4,4′-tetraminodiphenylmethane
(47) p-aminobenzophenone
(48) p,p′-diaminodiphenyl ether
(49) diphenylamine
(50) methyl red

The above list (excluding methyl red) was investigated to determine the effect of introducing various groups between two phenyl groups. The only compound found sensitive enough to have value as a chlorine reagent was (46) 3,3′, 4,4′-tetraminodiphenylmethane. However, both manganese and nitrite produce color with this compound in acid solution so it was eliminated from further consideration. All other compounds above produced only faint colors with chlorine. From this it appears that introduction of a group between two phenyl groups diminishes both the solubility of the compound and the intensity of color produced with chlorine.

Methyl red was not found satisfactory as it was decolorized by chlorine solution, but not by chloramine.

Table 2 summarizes the results obtained by the action of various substances upon compounds studied.

Discussion

As noted above, o-tolidine was found to be the best reagent for the determination of chlorine of the compounds investigated. Compounds giving satisfactory color with chlorine in alkaline solution were oxidized by air and those giving satisfactory color with chlorine in acid solution were oxidized by manganese and in some cases by iron. The correlation between oxidation potentials and interference due to manganese and iron should be considered. The oxidation potentials of tri and tetravalent manganese are high enough in acid solution to cause oxidation of o-tolidine. Ferric iron also produces some color on long standing in acid solution with o-tolidine. In alkaline solution both manganese and iron precipitate. However, the E_0 value for hypochlorite is high in alkaline solution (table 1). This

implies that a compound to be relatively free from interference by manganese and iron must be used in alkaline solution. No such compound was found in this investigation because those compounds which produced satisfactory colors with chlorine in alkaline solution were oxidized by air.

The starch-iodide test has been used in alkaline or slightly acid solution with some success for determination of chlorine in the presence of manganese by Scott (3) and Hinman (17). The explanation for this apparently lies in the low oxidation-reduction potential of +0.53 volt for the iodine-iodide system as compared with the higher potentials in alkaline solution of the hypochlorite and chloramine systems.

TABLE 1

Oxidation-reduction potentials

SYSTEM	E_0 (VOLTS)	E (VOLTS)				AUTHORITY REFERENCE NUMBER
		pH 5.3	pH 6.0	pH 8.0	pH 11.6	
$HClO-Cl^-$	1.500	1.27	1.22	1.13	0.88	(12, 13)
			1.12	0.96		(14)
Chloramine			0.87	0.67		(14)
$Mn^{++++}-Mn^{++}$	1.577					(15)
$Mn^{+++}-Mn^{++}$	1.511					(15)
NO_2^--NO	0.980					(16)
$NO_3^--NO_2^-$	0.950					(16)
$Fe^{+++}-Fe^{++}$	0.750					(12)

II. NITRITES IN THE O-TOLIDINE TEST

Various workers have reported nitrite interference in the o-tolidine test (4, 7, 8). The presence of nitrite has been attributed to the oxidation of ammonia by bacteria or chlorine (7, 8). Iron pipe is reported to catalyze the latter reaction (7). The dangers from nitrite, as shown below, are (*a*) that color may be produced with o-tolidine thereby giving high results in the test for free chlorine, and (*b*) that chlorine or chloramine may be reduced by nitrite. Scott has summarized the differences between the colors produced by action of o-tolidine with nitrite and o-tolidine with chlorine and has suggested a correction of 0.08 p.p.m. apparent chlorine reading for each 1.0 p.p.m. of nitrite nitrogen (4).

TABLE 2

*Effect of various substances on compounds investigated**

COMPOUND NUMBER	COLOR WITH						AIR OXIDATION		COMMENT
	Chlorine			Manganese 0.4 p.p.m. Acid	Nitrite 0.5 p.p.m. Acid	Iron 2.0 p.p.m. Acid			
	Acid	Neut.	Alk.				Acid	Alk.	
1	−		+			+		+	
2			Faint						Not sensitive enough
3	+	+	++					+	
4	+		++			+		+	
5	+		+			−		+	
6	+	+	+++			−		+	
7-8	−	+	++			−		+	
9	+		+			−		+	
10	−		Very faint						Not sensitive enough
11			Faint						Not sensitive enough
12	+	+	+						Not sensitive enough
13	−		+						Not sensitive enough
14	+	++				+	Slow		
15	+	++	+			+		+	
16	Faint	Faint	Faint						Not sensitive enough
17	Very faint		Very faint						Not sensitive enough
18	++		+						
19	−		Very faint						Not sensitive enough
20-21	−		−						
22			Very faint						Not sensitive enough
23-24	−		−						
25-26	Very faint								Not sensitive enough
27	++		Faint	+	+			Slow	
28	++		+	+	+				Color fades
29	Faint	Faint	Faint						Not sensitive enough
30-33	−		−						Very insoluble
34	++		−	+					
35	++		−	+	+	+			
36	++		−	+					
37	++ (F)		−	+ (F)	++	−			
38	++ (F)		−	+ (F)	++	−			
39	++		−	+ (F)	+				
40	−	Faint	−						Not sensitive enough
41-42	+		−						Reagent highly colored
43	Very faint		−						Very insoluble
44	Faint		−						Not sensitive enough
45									Very insoluble
46	++		−	+	++				
47	−		−						Very insoluble
48	Faint		Faint						Not sensitive enough
49	Very faint		Very faint						Not sensitive enough
50	Decolorized								

* Intensity of color is indicated by number of + marks.
(F), color fades.

Experimental

Work carried on in this laboratory showed that as little as 0.05 p.p.m. of nitrite nitrogen would produce detectable color with o-tolidine on standing for 7 minutes, which color increased on standing and in 60 minutes matched the 0.02 chlorine standard. Where 0.20 p.p.m. nitrite nitrogen was used, detectable color was produced in 3 minutes, false chlorine reading of 0.03 p.p.m. in 15 minutes and 0.05 p.p.m. in 60 minutes. The addition of excess HCl was found (1) to cause fading of the nitrite o-tolidine color when added after the color had developed and (2) to inhibit formation of the nitrite o-tolidine color when added previous to addition of o-tolidine. Quantitative data

TABLE 3

NITRITE NITROGEN USED	HCl (1:10) ADDED	TOTAL HCl	APPARENT CHLORINE (30 MIN.)	pH
Effect of addition of acid to o-tolidine nitrite color				
p.p.m.	*cc.*	*cc.*	*p.p.m.*	
1.0		0.5 (O. T.)	0.07	2.0
	0.5	1.0	0.04	
	1.0	1.5	0.03	
	2.0	2.5	0.03	
Effect of addition of acid to nitrite (0.5 cc. o-tolidine then added)				
1.0	0.5	1.0	0.02	1.75
	1.0	1.5	0.02	

to show the effect of acid concentration and pH on nitrite o-tolidine color are given in table 3. Nessler tubes (50 cc.) were used.

The results indicate that addition of excess acid is most effective previous to addition of o-tolidine and that pH values below 2.0 diminish nitrite o-tolidine color.

In contrast to the production of nitrite o-tolidine color (which is generally supposed to cause high results in the o-tolidine test) it was found that the intensity of o-tolidine-chlorine or chloramine color was decreased when nitrite was added after the color had developed. This led to an investigation of the relations existing between chlorine, chloramine, nitrite and o-tolidine in solution.

Confirming Hulbert (8) it was found experimentally that chlorine and nitrite cannot exist long in solution at the same time. Theoret-

ically, this is indicated by the oxidation-reduction potentials of the systems involved (table 1). Quantitative data showing the relations existing between chlorine, chloramine, and nitrite in acid and neutral solution were obtained as follows:

In 50 cc. Nessler tubes were placed amounts of standard sodium nitrite solution such that the final concentrations would range from 0.03 to 0.24 p.p.m. nitrite nitrogen. Chlorine solution was then added so that the chlorine concentration would be 0.30 p.p.m. To each of one set of tubes was added 1.0 cc. of 1:10 HCl (same strength acid as used for standard o-tolidine reagent) to the second set was added 0.5 cc. HCl and to the third no HCl. The mixtures were allowed to stand for 5 minutes and remaining nitrite then determined by Standard Methods procedure (18). Results are given in table 4-A.

The above procedure was repeated except that 0.30 p.p.m. monochloramine was used and the mixtures allowed to stand in the dark for 30 minutes before determining final nitrite. Results are given in table 4-B.

A comparison of average nitrite nitrogen oxidized by the two compounds shows the following:

Average nitrite nitrogen oxidized

	1 cc. HCl	0.5 cc. HCl	No HCl
	p.p.m.	*p.p.m.*	*p.p.m.*
By 0.30 p.p.m. chlorine (5 minutes).....	0.074	0.071	0.077
By 0.30 p.p.m. chloramine (30 minutes).....	0.066	0.072	0.034

Theoretically, 0.30 p.p.m. of chlorine or equivalent chloramine should oxidize 0.060 p.p.m. of nitrite nitrogen to nitrate. The table above shows that in acid solution both chlorine and chloramine oxidize nitrite quantitatively. In neutral or basic solution, chloramine oxidizes a part of the nitrite. Therefore, chloramine and nitrite can exist simultaneously in solution, so long as the solution is not acid. This raises the question as to what happens in the o-tolidine test when acid o-tolidine reagent is added to water containing both chloramine and nitrite. If part or all of the nitrite is oxidized upon acidification and therefore does not react with o-tolidine, a blanket correction for nitrite of 0.08 $\times$ nitrite nitrogen = apparent chlorine (4) would not be feasible.

In order to investigate the possibility of reduction of chloramine

by nitrite when acid o-tolidine solution is added, the data shown in table 5 were obtained. Readings were made at the end of 30 minutes.

The above data show that concentrations up to 0.75 p.p.m. nitrite nitrogen cause high readings for chloramine. Concentrations greater than 0.75 p.p.m. nitrite nitrogen cause the readings to diminish so

TABLE 4-A

Oxidation of nitrite by 0.30 p.p.m. chlorine (5 minutes)

INITIAL NITRITE NITROGEN	NITRITE N OXIDIZED		
	1 cc. HCl	0.5 cc. HCl	No HCl
p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*
0.03			
0.06			
0.09	0.085	0.075	0.056
0.12	0.070	0.072	0.075
0.15	0.072	0.080	0.075
0.18	0.085	0.065	0.090
0.24	0.060	0.065	0.090
Average.....	0.074	0.071	0.077

TABLE 4-B

Oxidation of nitrite by 0.30 p.p.m. chloramine (30 minutes)

INITIAL NITRITE NITROGEN	NITRITE N OXIDIZED		
	1 cc. HCl	0.5 cc. HCl	No HCl
p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*
0.03			0.020
0.06			0.035
0.09	0.060	0.075	0.042
0.12	0.060	0.072	0.040
0.15	0.075	0.075	0.035
0.18	0.070	0.070	0.030
0.24	0.066	0.070	0.035
Average.....	0.066	0.072	0.034

that with increasing nitrite concentration apparent chlorine reading becomes too low. These facts indicate that high concentrations of nitrite do reduce chloramine in the o-tolidine test. If a subtraction of 0.08 p.p.m. of false color for each 1 p.p.m. nitrite nitrogen be made it is seen that the calculated value obtained for chloramine actually

becomes negative where nitrite nitrogen is very high. In other words, low nitrites tend to cause high o-tolidine readings for chloramine and high nitrites tend to cause low o-tolidine readings for chloramine.

As shown above, a correction factor for nitrite is unsatisfactory, but increasing the HCl concentration in the o-tolidine test diminishes nitrite interference. Therefore o-tolidine solution was made up as specified in Standard Methods of Water Analysis (18) except that 0.5 gram o-tolidine and 150 cc. concentrated acid were used. The volume of reagent added to the sample tested was twice the volume specified by Standard Methods (i.e., 2.0 cc. of reagent per 100 cc.

TABLE 5

Effect of nitrite upon determination of chloramine

NO_2^-N	READINGS FOR NH_2Cl			
	0.30 p.p.m.	0.18 p.p.m.	0.10 p.p.m.	0.04 p.p.m.
p.p.m.				
0.00	0.30	0.18	0.10	0.04
0.10	0.30	0.18	0.10	0.04
0.30	0.30	0.23	0.12	0.05
0.50	0.35	0.23	0.13	0.06
0.75	0.38	0.30	0.18	0.10
1.00	0.33	0.27	0.17	0.08
1.50	0.20	0.08	0.09	0.06
2.00	0.20	0.08	0.06	0.06
3.00	0.10	0.04	0.04	0.04
5.00	0.06	0.04	0.04	0.04

sample instead of 1 cc. of reagent per 100 cc. sample). In this way the acid concentration in the sample tested was three times, and the o-tolidine concentration the same as, that used in the Standard Methods test. The result was that nitrite interference was greatly diminished, but the readings obtained averaged 25 per cent lower than the true chloramine values. This indicates that high acid concentration not only inhibits production of o-tolidine-nitrite color, but also favors reduction of chloramine by nitrite so that low chloramine readings are obtained. However, such values are more nearly correct than those obtained by the use of a correction factor for nitrite where the latter is high. In addition, the modified reagent provides sufficient acid to react with high alkalinity and 15 minutes

is sufficient for development of full color with chloramine. Interference due to ferric iron is diminished by use of the modified reagent.

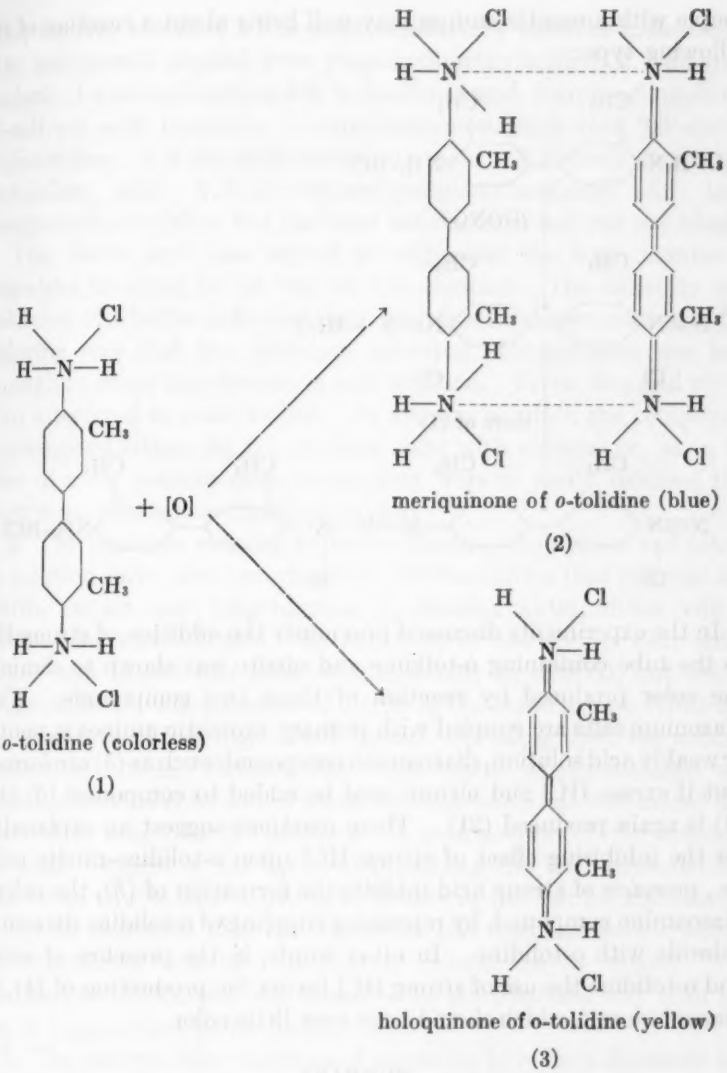
From the above it is apparent that the use of o-tolidine made up in higher acid concentration than specified by Standard Methods of Water Analysis (18), also suggested by Scott (4), is preferable to the use of a correction factor for nitrites.

III. NATURE OF ORTHO-TOLIDINE REACTIONS

The above considerations warrant some discussion of the reactions of o-tolidine. Willstätter and Kalb first showed that mild oxidation of benzidine produced a green substance and that upon oxidation with silver oxide or lead peroxide a deep yellow quinonoid substance was formed (19, 20). This compound contained two less hydrogen atoms than benzidine and was p,p′-diiminodiphenyl. Such fully oxidized products of diamines were termed holoquinones. In addition to the holoquinones, Willstätter and Piccard isolated colored, crystalline, partial oxidation products of diamines which were called meriquinones (21). For example, Wurster's red is the meriquinone produced by partial oxidation of p-aminodimethylaniline. The structure of meriquinones was shown to be analogous to that of quinhydrone, but meriquinones are not necessarily composed of equimolecular parts of oxidant and reductant.

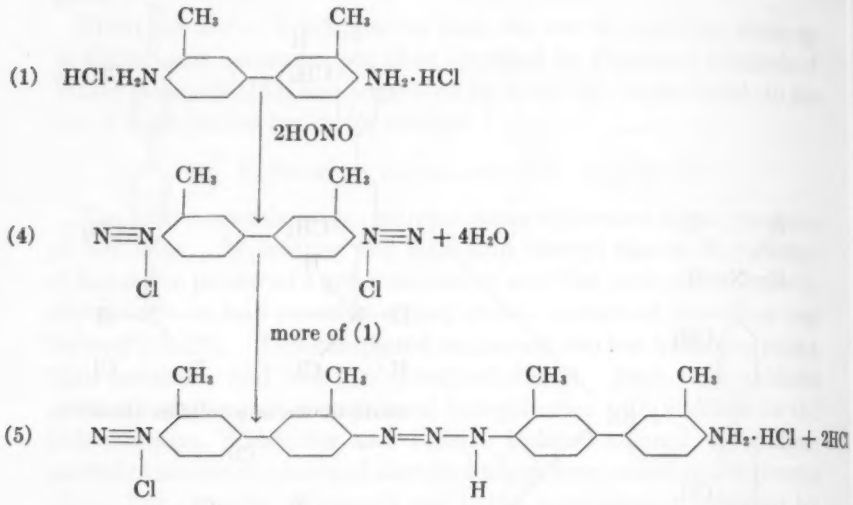
Clark, Cohen, and Gibbs applied the above considerations to the o-tolidine test and by means of potentiometric and spectrophotometric studies explained the varying color reactions shown by o-tolidine (11). The reactions involved are shown on page 1659. From these reactions it became evident that the variations in color experienced in the o-tolidine test were due to the superimposing of different degrees of oxidation upon the effects of variable pH. The use of strong hydrochloric instead of acetic acid favors the development of (3) instead of (2) with resultant greater stability. Likewise, the concentration of o-tolidine present is important since low concentration favors the formation of the completely oxidized form or holoquinone.

The reaction of nitrite with o-tolidine, while not explained previously, may be of different nature than the above. The color produced by the action of nitrite on o-tolidine is of different hue and slower in development than that produced with chlorine. If standard o-tolidine reagent be added to an acid solution of sodium nitrite



and standard alpha-naphthylamine solution added to the mixture, a red color develops slowly which acquires great intensity in 30 to 60 minutes. This color reaction indicates diazotization of o-tolidine with nitrous acid, followed by coupling with alpha-naphthylamine. In the standard o-tolidine test for chlorine there is no alpha-naphthylamine present, of course, but the tendency of diazonium salts to

couple with aromatic amines may well bring about a reaction of the following type:



In the experiments discussed previously the addition of strong HCl to the tube containing o-tolidine and nitrite was shown to diminish the color produced by reaction of those two compounds. When diazonium salts are coupled with primary aromatic amines in neutral or weakly acid solution, diazoamino compounds such as (5) are formed. But if excess HCl and nitrous acid be added to compound (5) then (4) is again produced (21). These reactions suggest an explanation for the inhibiting effect of strong HCl upon o-tolidine-nitrite color, i.e., presence of strong acid inhibits the formation of (5), the colored diazoamino compound, by repressing coupling of o-tolidine diazonium chloride with o-tolidine. In other words, in the presence of nitrite and o-tolidine the use of strong HCl favors the production of (4), the diazonium salt, which should have very little color.

SUMMARY

1. A study has been made of the possibility of elimination of interference in the color test for free chlorine, by applying the principle of oxidation-reduction potentials to various oxidant and indicator systems. Fifty compounds were investigated and a study was made of the relation of structure and position of groups in substituted benzidine derivatives to the action of the compound as an indicator in the

test for free chlorine. The most satisfactory chlorine indicators of the compounds studied were p-aminodimethylaniline, 2,4-diaminoanisole, 1-amino-8-naphthol-3, 6-disulfonic acid, 2-amino-8-naphthol-6-sulfonic acid, benzidine, 3-benzidinemonosulfonic acid, 3,3′-dichlorobenzidine, 3,3′-benzidinedisulfonic acid, 3,3′-diethylbenzidine, o-tolidine, and 3,3′,4,4′-tetraminodiphenylmethane. Of these compounds o-tolidine was the most satisfactory, but was not ideal.

The above work has served to emphasize the large number of variables involved in the test for free chlorine. The difficulty with selection of a better indicator than o-tolidine for determination of free chlorine was that the oxidation potential of manganese was high enough to cause interference in acid solution. Ferric iron and nitrite also interfered to some extent. In alkaline solution the compounds investigated either did not produce color with chlorine or, as in the case of some benzene derivatives, they were so easily oxidized that they were affected by dissolved oxygen.

2. The relations existing between chlorine, chloramine and nitrite in solution have been investigated. It was shown that chlorine and nitrite cannot exist long together in distilled water, either with or without addition of acid. In contrast, it was shown that chloramine and nitrite can exist simultaneously in neutral, but not in acid solution. The presence of nitrite in the standard o-tolidine test for chloramine gives high or low results depending upon the concentration of nitrite. Greater than 0.75 p.p.m. nitrite-nitrogen was found to reduce chloramine when the acid o-tolidine was added and allowed to stand for 30 minutes. A modification of the standard o-tolidine reagent which involved increasing the HCl concentration was found to diminish nitrite interference in the test for chloramine. With the increased acid concentration low readings were obtained for chloramine due to reduction of chloramine by nitrite. The modified o-tolidine test was found to be more satisfactory than the use of a correction factor for nitrite.

3. The various color reactions of o-tolidine have been discussed and experimental evidence obtained for the formation of a diazonium salt from o-tolidine and nitrite. It is indicated that the diazonium salt couples with more o-tolidine to give a yellow diazoamino compound. The presence of strong HCl is shown to diminish intensity of the o-tolidine-nitrite color by favoring the production of o-tolidine diazonium chloride instead of the more highly colored diazoamino compound.

CONCLUSIONS

Previous investigations (4, 23, 24) and the results in the present paper indicate that a more strongly acid solution than that specified by Standard Methods of Water Analysis (18) is advisable for the determination of free chlorine. For the modified reagent 0.5 gram of o-tolidine and 150 cc. of concentrated HCl are made up to 1000 cc. with distilled water by a similar procedure to that described in Standard Methods of Water Analysis. Addition of 2.0 cc. of the modified reagent to 100 cc. of sample has the following apparent advantages: (1) maximum color with chloramine develops in 15 minutes; (2) color due to nitrite is avoided and (3) interference due to iron is minimized. Whether the acid concentration in the test should be made three times that in the present Standard Methods test, as specified above, or four times, as specified by Scott (25), depends upon the alkalinity of the sample.

The above reagent does not avoid interference due to manganese.

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LANDOLT - BÖRNSTEIN:

DISCUSSION OF PAPERS ON ORTHOTOLIDINE TEST

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In the absence of the scheduled paper by Dr. Buswell, the following comments on the influence of manganese upon the orthotolidine test have been based upon published papers of Dr. Buswell and others. This literature and the paper by Mr. Hulburt are of great value in focusing attention upon the two major difficulties encountered when making the orthotolidine test. This test is of paramount importance as it provides practical and convenient means of effectively controlling the disinfection of water and sewage. The simplicity of the test, however, has been misleading and undue confidence has been placed in the results by those not accustomed to consider the chemistry of the test.

The defects of the orthotolidine test may be classified into two groups:

(a) The inherent defect due to the fact that the test indicates the extent of reaction between the reagent and the chlorine liberated by the acid of the reagent, rather than the intensity of disinfection by the available chlorine in the unmodified water. This inherent defect justifies serious search for a better test.

(b) The second group of defects may be classified as that due to errors resulting from the presence of interfering substances such as iron, manganese and nitrites. The papers under discussion deal in detail with the latter factors.

MANGANESE

Manganese is not normally present in many water supplies in New York State, to judge from the infrequency with which errors in the orthotolidine test are noted, where manganese would be the likely cause. Manganese is known to be present in about 15 supplies, however, including the supplies of Albany, Hartwick and the Croton supply of New York, where a concentration giving a false color equivalent to as high as 0.35 p.p.m. chlorine has been present. It is

significant to note that oxidized manganese is insoluble in water, and hence manganese is present only in well waters, or waters from deep reservoirs where decomposition of organic matter depletes the dissolved oxygen and permits reduction of the manganese in the soil. Manganese, therefore, is chiefly present in the deeper portions of large reservoirs, or throughout such reservoirs during periods of seasonal over-turn. This difficulty may be minimized by drawing water from intakes located near the surface, where possible, because the reduced form of manganese in the bottom water is oxidized and precipitated to a major extent when the water reaches the surface during periods of over-turn.

Most modifications of the orthotolidine test suggested to eliminate errors due to manganese are either too technical or are too cumbersome for use in plant control by those lacking technical training. Furthermore, the suggested methods have been found to modify the state of oxidation of the manganese and iron compounds, which in turn changes the effects that these substances have on the orthotolidine reagent.

Pending the development of a satisfactory and simple orthotolidine test which compensates for errors due to manganese, the Department has tentatively suggested that the manganese "blank" or error be determined by adding the reagent to one sample of chlorinated water in the usual manner, and also to another sample of chlorinated water which has been allowed to stand 24 hours for the residual chlorine to disappear. This procedure assumes that the reaction between manganese and chlorine is completed at the end of the 10 minute period allowed before the reagent is added to the first sample and that no further change in the state of oxidation of the manganese occurs during the 24 hour period. Further study is required to permit a definite decision regarding this procedure, but the indications are that the results are more reliable than the only other simple procedure, namely, the boiling method suggested by Enslow. This tentative procedure, however, cannot be used with water treated with chlorine and ammonia, because a true residual may persist for 24 hours.

NITRITES

We have not experienced difficulties due to interference from nitrites in making the orthotolidine test, except at swimming pools and a few filtered supplies where the ammonia treatment is utilized. Mr. Hulburt's valuable paper, however, is of timely interest in point-

ing out that the biological oxidation of ammonia may greatly increase the chlorine demand of the water, as well as interfere with the orthotolidine test. This difficulty has been especially significant at Peekskill, New York, where a soft water with a pH of about 6.5 is filtered through conventional slow sand filters. Prechlorination with about 0.4 p.p.m. ammonia and 1.2 p.p.m. chlorine, followed by post-chlorination with 1.0 p.p.m. chlorine alone, was used during the summer of 1933. During this period the filtered water had an unduly high chlorine demand, as indicated by the required final dose of 1.0 p.p.m. chlorine to produce a 0.2 p.p.m. residual. It was found that all of the residual ammonia present in the unfiltered water was being oxidized to nitrites, which in turn were being changed to nitrates by the post-chlorine dose. No ammonia, therefore, was present in the filtered water at this time, but when the water temperatures were lower, both ammonia and chloramines from the pre-treatment went through the filters. As a result of this experience, it was recommended that the pre-ammonia dose be only sufficient to react with the pre-chlorine dose, and that a second ammonia dose be applied to the filtered water to react with the post-chlorine dose.

In general, there is an increase in the nitrite content of the effluents of rapid sand filters in summer where pre-ammonia treatment is practiced, but the increase is not enough at most plants to increase appreciably the chlorine demand of the water or interfere with the orthotolidine test.

We have no evidence of the formation of nitrites in reservoirs and mains holding water containing both chloramines and excess ammonia, although relatively few quantitative data are available. It is our impression, however, that ordinarily some suitable habitat for nitrifying bacteria would be required, such as a filter bed.

The literature contains frequent references to differences of opinion relative to the orthotolidine test of chlorine-ammonia treated water. It would appear that some of this difficulty is due to the presence of nitrites. Our laboratory has substantiated the statement made by Mr. Hulburt, namely, that very small concentrations of nitrites will produce a definite color with orthotolidine, in contrast to published statements by Enslow, Buswell and others. It has been found that nitrites in concentrations between 0.01 and 0.6 p.p.m. will produce a false color similar in hue to that produced by chlorine. Higher concentrations of nitrites, however, produce a brownish yellow color. Unfortunately, however, we also find that this false color is produced

in the dark, although not to as pronounced an extent as when the reaction occurs in the light. We, therefore, cannot at this time support the findings of Mr. Hulburt relative to the possibility of overcoming errors due to nitrites by having the orthotolidine reaction proceed in the dark.

Our preliminary study of the necessary reaction time between chloramines and orthotolidine in the presence or absence of nitrites has indicated that the reaction period should be quite long, namely, about 20 to 30 minutes, to indicate the true concentration of chloramines. We cannot agree with Mr. Hurlburt's conclusions, therefore, because we find that the color present after a 5–10 minute reaction period is due almost entirely to nitrites rather than chloramines, and that the additional color resulting after a further reaction period of twenty minutes is due to both chloramines and nitrites, rather than nitrites alone. Both substances, therefore, produce the color throughout the reaction period. This whole subject is full of complications, and hence more definite statement cannot be made pending the completion of elaborate studies being made by the Division of Laboratories and Research of our Department. It is our hope, however, that the use of higher pH values with some of the existing indicators will offer a satisfactory means of overcoming interference by manganese and nitrites. Such procedures, however, might not be satisfactory with chlorine-ammonia treated water.

In summary it appears that the following practical conclusions may be drawn:

1. That water should be secured from near the surface of deep reservoirs when manganese may be present in the water from the lower depths.

2. That special precautions should be taken in making the orthotolidine test of chlorinated water secured from large reservoirs during periods of seasonal overturn, when manganese may be distributed throughout the reservoir.

3. That chlorine should be added to water at a point where the ammonia dose has become thoroughly mixed in the water, but where there will be insufficient time for the ammonia to be subject to biological oxidation before the chlorine is added.

4. The ammonia dose should be kept at a minimum, both to improve chlorination and to eliminate excess ammonia, except when this excess is needed to prevent chloro-phenol tastes.

5. Ammonia should be added twice when split or double chlorination is practiced, to avoid biological oxidation in the filters.

DISCUSSION OF PAPERS DEALING WITH CHLORINATION

By Linn H. Enslow

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It is difficult to reconcile the claims of nitrite interference with the observation that unchlorinated sewage effluents fairly rich in nitrites fail to produce a color with orthotolidin. However, the period of contact in sewage testing never exceeds 5 to 10 minutes. Where nitrites are excessively high, a brownish color appears after a 10 minute contact. None the less there are no grounds which justify the 30-minute contact as specified in Standard Methods. Why the change was made remains an open question.

Attention is called to the recently suggested method by R. D. Scott in the May, 1934, issue of *The Journal*, wherein manganese is precipitated by flocking the sample with magnesium hydrate produced from magnesium sulphate and caustic soda. In case nitrites are found, a correction (p.p.m. Nitrite N. X0.08) should be deducted from the maximum reading of apparent chlorine value. The development of color in the dark and a contact period limited to 10 minutes at 20°C. or above should, moreover, render nitrite interference of inconsequential proportions. Manganese interference is to be more seriously considered and the hydrate precipitation method developed by Scott seemed to have certain advantages over other less dependable methods—including the method I have suggested, involving heating to dissipate the chlorine and determining the manganese effect (blank) by testing the boiled, cooled and diluted sample with orthotolidin. The method of reducing manganese with hydrogen peroxide, proposed by Adams and Buswell, is tricky and has to be carefully conducted to insure complete manganese reduction without destruction of the chlorine present.

Regarding the ammonia-chlorine process, if for no other reason than economy, the ammonia as a general rule should be added after filtration. Fortunately, Detroit was employing prechlorination and, therefore, the false residuals were not accompanied by a breakdown in plant efficiency.

In commenting on the comprehensive review of the ammonia-

chlorine process by Mr. Smith, it is apparent that a most practical attainment is that of holding in check the biological degradation taking place in "dead-end" mains and sluggish flow sections of the system. The elimination of the necessity of constant bleeding and frequent flushing of dead ends is a matter of consequence to the maintenance department. The reduction of consumer complaints of tastes and discoloration by iron stains and the bacteriological "flare-ups" on the system which occur in warm weather is of great satisfaction to the chemist and superintendent of filtration, who having turned out a fine product at the plant has to "take it on the chin" when it comes to the lack of control of subsequent developments at points on the system remote from the plant.

About three years ago, Riddick and Linderman of the U. S. Cast Iron Pipe Company put forth a claim that much in the way of tuberculation of mains could be attributed to biological phenomena and that chemical attack was not alone responsible. Later, British investigators offered data which served to confirm the claims of Riddick and Linderman. The general report that "red-water" or "black-water" troubles have been materially modified, by carrying residual chloramine chlorine constantly to the far reaches of the distribution system, might be considered as further proof that degradation of organic matter and corrosion and tuberculation go hand in hand. The results reported from Utica, N. Y., to the effect that a large and long gravity main was holding up, if not actually gaining in carrying capacity, since cleaning and introduction of the ammonia-chlorine process at its intake end, is added evidence as to what may be expected if biological control will suppress tuberculation. Further confirmation of these observations will constitute a development of high economic as well as technical importance.

In ammoniation there is a possibility of increased economies and also insurance of rapid effective sterilization if the conditions favor the application of chlorine first and thereafter only that ammonia required to convert the residual chlorine to chloramines, rather than the whole of the chlorine dosage. The scheme might be considered as a form of super-chlorination and de-chlorination with ammonia. Chlorine being so materially cheaper than ammonia one can use considerably more, provided ammonia could be saved thereby. The results will be: greater destruction of organic matter; certain and high bacteriological efficiencies; economy.

In commenting on Mr. Griffin's studies, the results are a valuable

contribution and particularly so since they represent plant scale findings at three different points. The conclusion that twice as much residual chlorine as chloramine is required to do the same work as chlorine alone in reasonable periods of contact (under 2 hours), was in line with observations at other points—particularly in connection with swimming pool chlorination. The studies of Mr. Griffin do not include waters with very low temperatures or waters which had a pH value above 7.8. Since the efficiency of chloramine chlorine is sharply affected by water conditioning (to pH 8.4 or above in softening or corrosion control), and by temperatures approaching freezing, there is need of extending and broadening the work, so well initiated by Mr. Griffin, so as to include waters of pH values above 7.8 at low temperatures.

The findings indicate the value of practicing pre-chlorination and post-ammoniation wherein contact after post-chlorine becomes a matter of little consequence and the "slow but sure" action of the chloramines becomes an asset and not a matter to be fearful of.

Mr. Cox's paper contains much information of value in the matter of available equipment and methods of small supply chlorination. Advice as to stabilization of hypochlorite solutions with alkali is timely and there is now available a dry ready prepared mixture (H.T.H. 15) which contains the proper proportion of soda ash and calcium hypochlorite to produce a stabilized solution of sodium hypochlorite. Mr. Cox did not list the Phipps-Bird solution feeder as an automatic or semi-automatic device, but it is adaptable to such use in connection with automatic pumping equipment and on variable flows also.

In connection with hypochlorite solution feed it is feasible to do two jobs at one time—i.e. add alkali for pH adjustment along with the chlorine through a single feeder. For the same purpose there seems no good reason why hydrated lime and hypochlorite might not be mixed in the correct proportion for dry feeding—i.e., dry dilution of hypochlorite with lime. In small supply treatment it is always preferable to have a reservoir or tank in the system, so arranged to have the water pass through the reservoir rather than have it merely floating on the system. By this scheme a more dependable result and uniformity of product should be secured at consumer's taps.

Mr. Hedgepeth should be complimented on his valuable and needed contribution. The ton-container vault with connections from it to the chlorinators seems to be a very practical safety scheme.

THE AIR-DILUTION METHOD OF ODOR DETERMINATION IN WATER ANALYSIS

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The direct quantitative chemical determination of most of the substances that impart odors to drinking water is rendered difficult and generally impossible by the wide variety and structural complexity of these substances as well as by the minute magnitudes of the concentrations in which they are significant. If odors were radiant in nature rather than corpuscular, some method of electrical amplification might solve the problem. As matters stand, however, the human nose is, at present, the most sensitive detecting instrument at our disposal and is likely to remain so for some time to come. Hence all systems of odor determination in water analysis so far developed call into play the use of the sense of smell of the observer. To place the determination on a quantitative basis, stricter than the present estimates included in Standard Methods of Water Analysis, a system of dilution of the odorous water with odor-free water has been proposed by Spaulding (1) and a system of dilution with air of the odor emanating from the water has been suggested by Fair (2). It is the purpose of this paper to describe a new instrument devised to simplify the air-dilution method and possibly also the water-dilution method and to comment on the reasoning underlying its design.

THE WEBER-FECHNER LAW

To begin with the instrument assumes the validity of the Weber-Fechner, or psychophysical, law. It may be well, therefore, to give a brief account of this law and its implications in odor determination.

If we introduce into a given volume of odor-free water an amount of odorous substance sufficient to create a distinct odor impression when the flask containing the water is smelled, we shall find that we must add a definite additional amount of the odorous substance before

we are able to recognize a distinct difference in the intensity of the odor emanating from the water. This additional amount represents the so-called threshold difference in odor concentration. We shall observe, furthermore, that the greater the initial concentration of the odorous substance, the greater will be the required additional amount. This fact was first recognized by Weber (3) in 1834. It remained for Fechner (4) to show 16 years later, however, that the required difference in concentration stood in a constant ratio to the underlying concentration of the odorous substance. That Weber's discovery related to the sense of touch rather than the sense of smell is not important since it was soon shown to apply equally well to all other types of sensation. The Weber-Fechner law states, therefore, that what are recognized as equal differences in sensation are produced by constant fractional increments in stimulus. Hence the so-called threshold differences are logarithmic differences or ratios.[1]

In order to obtain a starting point for our measurements we can refer them to the lowest concentration of odorous substance that can be sensed. This is called the threshold concentration of the odor. Expressed in grams of odorous material per cubic centimeter of air, this threshold concentration is designated an "olfacty."

In view of the limitation, previousy mentioned, that it is generally impossible in water analysis to ascertain the actual causative agents of an odor, we are forced to be content with a relative measurement, instead of an absolute one, by referring the strength of an odor to its threshold value which is obtainable by dilution of the odor-containing water or of the odor-containing air. If we adopt this procedure, we must decide next whether we wish to regard odor intensity as a physiological unit or as a quasi-physical unit. If we decide on a physiological standard, we shall wish to report the strength of an odor as being so many units greater than its threshold value. If we attempt to approach a physical measurement, we shall wish to express odor

[1] Expressed mathematically: $dy = k\frac{dx}{x}$ where dy is the minimum difference in sensation, $\frac{dx}{x}$ the ratio of the minimum difference in stimulus to the underlying stimulus, and k a constant depending upon the conditions of experiment. By integration $y = K \log\frac{x}{X}$ where y is the magnitude of the sensation, x the magnitude of the stimulus, K a constant, and X the magnitude of that stimulus at which the sensation becomes zero, *i.e.* the so-called threshold value of the stimulus for the particular sensation.

intensity as being so many times its threshold concentration. In other words, we are able either to follow the principles included in the present odor-intensity scale of Standard Methods by using the nose to estimate the relative strength of the odor observed, or to establish a new principle of measurement by using the nose to estimate the relative concentration of the odorous substance in the water analyzed. While these two methods of attack are not incompatible, it would seem most logical, as well as most informative, to adopt an odor scale that is based on the direct odor impression rather than the relative odor concentration. One scale, however, is readily converted into the other if we so desire.

The threshold difference, which might better be called the threshold ratio, appears to vary for different substances and may vary also for different observers. Values between 24 and 62 percent are reported in the literature (5), but our knowledge of the subject is quite meagre. As a first step in odor measurement, Fair (2) has suggested the use of a threshold ratio of 100 percent which will lie well within the range of precision attainable for different odors and by different observers. If this threshold ratio is employed, the strength of an odor may be expressed as the number of times that the odor must be diluted with an equal amount of odor-free air, or in the ratio of 2 to 1, before the threshold value of the odor is reached. This number of times has been called the pO value. A pO of *0* signifies, for example, that the odor is just detectable as encountered and need not be diluted to be sensed as the threshold value; pO *1* that it must be diluted *once* with an equal volume of odor-free air before the threshold value is reached; pO *2* that it must be diluted *twice* with an equal amount of odor-free air, etc. Stated in a different way, an odor strength of pO *4* means that the odor must be dispersed in $2\times2\times2\times2 = 2^4 = 16$ times the volume of air occupied by it at the time of measurement before the threshold intensity is reached. A ratio other than 100 percent may be found more useful in the future as we gain more experience in odor measurement, or it may apply better to certain specific problems. Spaulding (6) has set up a scale based on a threshold difference of approximately 25 per cent. In comparative tests made by different observers, it was found that trained workers may be expected to agree within two dilutions that differ by about 25 percent. This places the reliable precision of measurement at a threshold difference somewhere between 50 and 100 percent.

THE OSMOSCOPE

The osmoscope developed by the authors employs a dilution ratio of 100 percent but can be adapted to any other ratio if desired. The latest form of instrument[2] is shown in figures 1 and 2.

The instrument consists of four essential parts: (1) a cylindrical odor tube with open bottom and closed top perforated by a single hole on the top and banks of holes along the sides; (2) a cylindrical sleeve open at top and bottom and fitting snugly over the odor tube; (3) a cylindrical air tube open at the bottom, sliding snugly over the sleeve and perforated by banks of holes along the sides; (4) a nose piece capping the air tube and provided with a swinging joint permitting the adjustment of the nostril distance to suit the observer. All perforations are of equal diameter and hence possess equal hydraulic characteristics. The banks of holes in the odor and air tubes are arranged so that a proper setting of the sleeve will leave the following combinations of holes exposed.

NUMBER OF HOLES EXPOSED			RATIO OF ODOR TO TOTAL HOLES	pO VALUE
Odor	Air	Total		
16	0	16	$1:1 = 2^{-0}$	0
8	8	16	$1:2 = 2^{-1}$	1
5	15	20	$1:4 = 2^{-2}$	2
3	21	24	$1:8 = 2^{-3}$	3
1	15	16	$1:16 = 2^{-4}$	4
1	31	32	$1:32 = 2^{-5}$	5
1	63	64	$1:64 = 2^{-6}$	6

The proper settings to attain these combinations are marked on the instrument which can be locked in position by knurled screws.

To determine the intensity of an odor, the open end of the odor tube is inserted in the flask containing the water to be tested. The flask should be partly filled with water and should have been well shaken. Starting with the highest setting of the instrument (pO *6*), sniffing through the nosepiece will draw one volume of odor through the single exposed hole in the odor tube and 63 volumes of air through the 63 exposed air holes. The odor will thus be diluted 1:64 or $1:2^6$. If the odor is sensed in this dilution, its pO value is equal to or greater than pO *6*. If it is not, the setting is changed

[2] As manufactured by Eimer and Amend of New York.

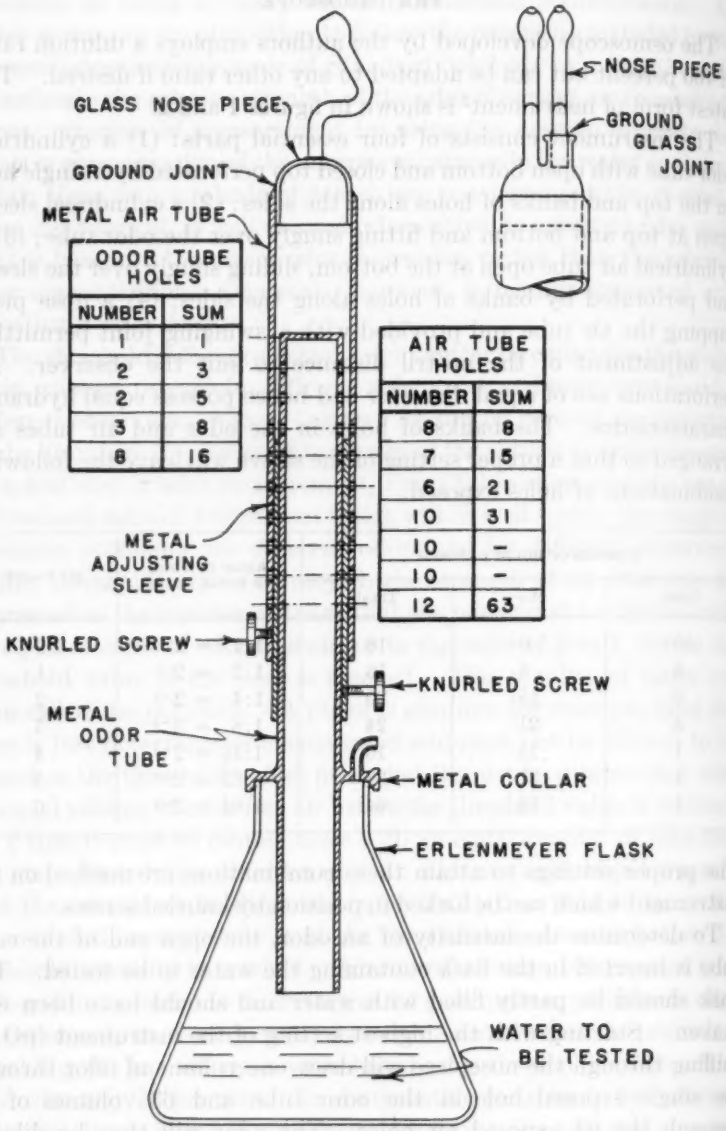

FIG. 1. OSMOSCOPE FOR USE WITH AIR-DILUTION METHOD OF ODOR MEASUREMENT

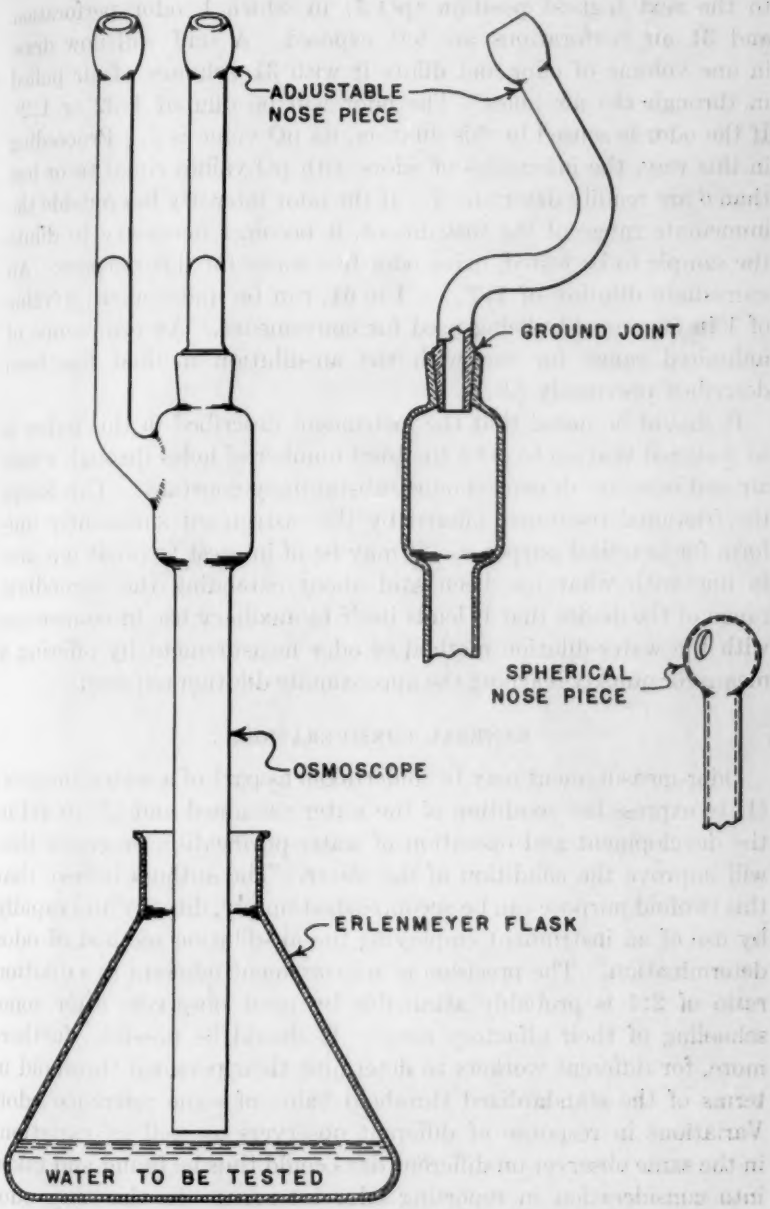

FIG. 2. OSMOSCOPE FOR USE WITH PRESENT "STANDARD METHODS" OBSERVATION OF ODOR OR WITH WATER-DILUTION METHOD OF ODOR MEASUREMENT

to the next highest position (pO *5*) in which 1 odor perforation and 31 air perforations are left exposed. A sniff will now draw in one volume of odor and dilute it with 31 volumes of air pulled in through the air holes. The odor will be diluted 1:32 or $1:2^5$. If the odor is sensed in this dilution, its pO value is *5*. Proceeding in this way, the intensities of odors with pO values equal to or less than *6* are readily determined. If the odor intensity lies outside the immediate range of the instrument, it becomes necessary to dilute the sample to be tested, using odor-free water for this purpose. An immediate dilution of $1:2^6$, *i.e.* 1 in 64, can be undertaken; a value of 1 in 50 probably being used for convenience. An osmoscope of unlimited range for use with the air-dilution method has been described previously (2).

It should be noted that the instrument described in this paper is so designed that up to pO *5* the total number of holes through which air and odor are drawn remains substantially constant. This keeps the frictional resistance offered by the instrument sufficiently uniform for practical purposes. It may be of interest to point out also in line with what has been said about extending the immediate range of the device that it lends itself to auxiliary use in connection with the water-dilution method of odor measurement by offering a means for quickly reaching the approximate dilution required.

GENERAL CONSIDERATIONS

Odor-measurement may be undertaken as part of a water analysis: (1) to express the condition of the water examined and (2) to aid in the development and operation of water-purification processes that will improve the condition of the water. The authors believe that this twofold purpose can be accomplished simply, directly and rapidly by use of an instrument employing the air-dilution method of odor determination. The precision of measurement inherent in a dilution ratio of 2:1 is probably attainable by most observers after some schooling of their olfactory sense. It should be possible, furthermore, for different workers to determine their personal threshold in terms of the standardized threshold value of some reference odor. Variations in response of different observers as well as variations in the same observer on different days could thus be found and taken into consideration in reporting odor intensity. In this way odor measurement could be placed more nearly on an absolute footing. So far as tests of odor removal are concerned, however, it is not

necessary that a standard threshold be reached by the individual observer. If he finds, for example, that a certain dose of activated carbon reduces the observed pO value by one unit and he wishes to reduce the odor by a second unit, it merely becomes necessary to double the dose The assumption is made in this connection that equal amounts of odorous material are absorbed by equal amounts of activated carbon.

The conformity of odor sensation to the Weber-Fechner law establishes an odor scale, such as the pO scale, which has a physiological basis and does not depart in concept from the sensory odor scale now included in Standard Methods except that it possesses no upper limits. The determinations of both color and turbidity in water analysis are similarly circumscribed by physiological (visual) responses. This is indicated by the rules included in Standard Methods for expressing the results of these determinations. The threshold difference, however, is smaller.

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DISCUSSION

M. WARREN COWLES (*Health Officer, Hackensack Water Company, New Milford, N. J.*): Professor Fair, in a joint paper with Wells, has just explained the basis of his proposed method for determination of odor and tastes by means of progressive dilution with air or water, and recording as pO and O in the case of odors, and pT and T in the case of tastes (1). Odors and tastes in public water supplies are becoming increasingly important and any method of simple and accurate quantitative measure of these qualities is welcome to the waterworks operator.

For the past six months, the writer has been engaged in a study by the Hackensack Water Company to determine whether or not

the flow of stray electric currents over water service pipes, will produce deterioration of the quality of water by the production of odors, tastes and discoloration. The method proposed by Fair was used as a means to permit comparison of odor and taste constituents on a direct quantitative or numerical basis. The results of the electrical research thus far available confirm and strengthen the hypothesis presented in a joint paper at the Chicago Convention in 1933 (2). Odors not detectable in the water from a series of laboratory test pipes reach a considerable intensity when the current is flowing and disappear when the current is cut off. Similar results have been obtained on a few field cases where reasonably complete data is available. The current appears also to produce a decided metallic astringent after-taste which gradually disappears when the current is removed.

The following procedure, using odor-free water, was adopted.

A 60 cc. sample of the water to be tested allowed to come to room temperature, 65–70°F., was poured into a graduate, progressively diluted and the pO values recorded along with the proper descriptive term. Tap water from the Hackensack supply was used for dilution purposes as it was practically odor-free as a result of treatment by activated carbon in the coagulation basin. The diluted samples for testing were poured into glass-stoppered Erlenmeyer flasks of 500 cc. capacity, as specified in the "hot odor" test of "Standard Methods." Each sample was then tested with the apparatus devised by Fair and Wells and referred to as a nosepiece. Scrupulous cleanliness of all the glassware is important in determining the point at which an odor disappears and it was found that, even in standing overnight in an ordinary water laboratory, appreciable odors would collect in the glass apparatus. The glassware was filled with odor-free water and the nosepiece well rinsed out before use and tested. Rerinsing of all apparatus has to be done frequently.

In the odor tests, duplicate determinations were made for odor, the first, cold odor after "Standard Methods" and second, the pO value (using odor-free water). Table 1 shows the results of these parallel observations on some 325 samples of water, most of them from the special electrolytic test pipes and the others from miscellaneous sources, watershed or distribution system. The pO values were grouped according to "Standard Methods" intensities with the use of intermediate values and the average pO value computed. For intensities up to 3 as of "Standard Methods," the use of the

nosepiece shows odor intensities much higher than the intensities by Standard Methods. If expressed in terms of odor concentration O, the values are about 200 percent higher. The pO value by water-dilution method seems to be a much more sensitive one than that of "Standard Methods," probably even more sensitive than the "hot odor" test, as ordinarily done. It is perhaps equal in sensitivity to the modified hot odor test (50°–60°C.).

While opportunity has not been afforded for a comparison of results with many experimenters, the pO values obtained by two other observers in our laboratory in several comparative tests, do not appear to vary at most more than one or very occasionally two dilutions or a variation in pO value of 1 or 2. The observations by any one observer made on the same sample on different days will

TABLE 1

Relation between odor intensities by two methods

ODOR INTENSITY AFTER STANDARD METHODS	NUMBER OF SAMPLES TESTED	ODOR INTENSITY (AFTER FAIR) pO		
		Maximum	Minimum	Average
½ or less than 1	38	3.0	0.5	1.72
1	135	5.0	0.5	2.24
More than 1, less than 2	42	4.0	1.0	2.74
2	75	4.5	1.0	3.00
More than 2 less than 3	11	6	2.0	3.68
3	24	6	2.0	3.93

apparently not differ more than one dilution or a pO value of 1. It must be borne in mind that disappearance of an odor is a much more delicate test than to attempt to direct smelling to estimate the actual intensity of an odor, where a great variety of observations by different observers are usually found.

Careful ventilation control in the laboratory where the tests are made is essential. There must be freedom from the strong odors resulting from other laboratory operations. The sniffing must be confined to odors diluted to approximately the end point or quiek fatigue of the nerves in the olfactory area may result. A hot, dry atmosphere in the laboratory during the heating season, should be avoided. The common cold and other ailments may likewise interfere. Where fatigue does occur, exposure to fresh outside air will help to reduce the effect, but a change of activity for a half hour is much better.

The intensity and descriptive term for the odors by the Standard Methods procedure is usually a reaction on the observer from a mixture of odors and the pO method with water dilution and special nosepiece at once shows that several constituents are present in different concentrations with different pO values. End points for the several constituents can be readily recorded and the disappearance of a particular constituent can be checked in the various processes forming the water purification equipment.

The sensitivity of the nosepiece is most important and apparently is dependent upon several different factors. It must be *comfortable* when held in position in the nostrils. A device which is uncomfortable may produce a reaction not unlike that of a foreign body and greatly interfere with sense of smell. A number of different nosepieces all of glass have been prepared and their sensitivity varies greatly when tested with the same sample of water. The small nostril tips must be adjustable to fit different persons and each person should have his or her own nosepiece. The first nosepieces obtained from Fair had a cork stopper producing a faint residual musty odor regardless of the treatment of the cork, and ground glass joints were substituted. The device must be capable of easy cleaning to prevent the effects of odor adsorption and therefore inaccurate pO values. These remarks apply equally to the new osmoscope just described by Fair and Wells. Several determinations of pO value were obtained by using a glass syringe-like device not unlike the metal one now described, utilizing laboratory air for dilution and comparing with pO values obtained by the odor-free water dilution method. In general, the air dilution results, showed lower pO values by two or three dilutions. The maximum pO value was 3. It is now believed that this was due partially to uncomfortable nostril tips and to the tendency of odors to be adsorbed on the ground glass interior surface of the piston.

Tests on some 25 samples of odor-containing water have been made with the new all-metal osmoscope and nosepiece combined into one instrument with a maximum pO value of 6, but with a cork, well boiled in paraffin, to hold the nostril tips. Parallel tests have been compared with the glass syringe type of osmoscope and with the water-dilution method and an all glass nosepiece. pO values of the samples tested covered a rather wide range. In each case, the water-dilution method showed a pO value at least 1 and sometimes 2 higher than that found with the metal apparatus and from 2

to 4 higher with the one of glass. The metal type still has a tendency to adsorb odors requiring cleaning after 4 or 5 tests but this is offset by the greater convenience and saving of time. With the metal and glass osmoscope, it seems difficult to secure separation of the several constituents and their respective pO values and at times with low pO values, to even apply a descriptive term. Further improvement in the apparatus may correct this and for many purposes, the ability to separate various constituents may not be of any value.

The original mercury apparatus for air dilution, with unlimited range (1) was likewise tried and it was found to have several definite limitations. Odors of pO value of less than 3 liberated from water could not be determined, due probably to the adsorption of odors by the mercury and by the glass surfaces as well and to an uncomfortable nosepiece. It was expected that chemical odors, chlorine, hydrogen sulfide, and the like, might form a chemical combination with mercury. Laundry waste with a strong soapy odor showed a pO of 4 with the mercury device, as compared with the pO value with the water dilution method 5.5, which on an odor concentration basis meant an error of roughly 250 percent. The device is of great value, with certain limitations, for the determination of very strong odors where any measure of intensity is now difficult to obtain and further study will doubtless indicate changes in the apparatus which will make it still more effective.

Observations made on the odor characteristics of the water supply furnished by the Hackensack Water Company rendered virtually odorless by activated carbon, indicates that under certain conditions, very minute quantities of certain residual odors can be noticed by a consumer. Some method of concentration of these dilute odors is needed utilizing perhaps the distillation method used at the plants of the American Water Works and Electric Company or by some modification of the use of an all metal-osmoscope.

TASTE IN WATER

The taste of various waters differs considerably as might be expected, due probably to their mineral content and in certain cases to metal content. Water from taps on the consumers' premises show a different taste from water which has passed through the mains of the distribution system. Water from locations where considerable stagnation takes place also has a different taste from water in other areas where circulation is more rapid. By the use of

the progressive dilution method, it is possible to ascertain difference in taste and place these values on a numerical basis, giving them an importance comparable with the other commonly done physical and chemical determinations.

Determination of tastes were made by utilizing tap water as the standard, taken from a bleeder on the line supplying the experimental electrolytic test service pipes. Dilutions were made with this water with a graduate using 50 cc. samples of the sample at room temperature and the various dilutions set up in a row of clean 250 cc. beakers. Sufficient dilutions are made to eliminate the taste and the sipping process is started at the highest dilution gradually working backward until there is a definite change in taste. The end point is not always as clear as for odor determinations but good results are nevertheless possible after a little experience.

Tests made on water standing in the experimental electrolytic pipes for two days showed pT values of 5 to 10, without electric current and from 15 to 25 where current was applied.

The actual pT value of the water used for dilution purposes apparently does not have a very great effect on the tests where the actual pT value of the sample is more than double the pT of the water used for dilution purposes. Dilution water having a pT of 8 produced a pT change of only 2 dilutions for a sample that had a pT value of over 20 determined in the usual way. The end point is much less easy to determine and fatigue occurs much more rapidly. Further research can probably develop a standard taste-free dilution water which can be easily produced in any laboratory and, therefore, make determinations comparable between different observers.

A few comparative tests in our laboratory have indicated a difference in pT value of 3 to 4 as a maximum between three different observers where samples of water with pT values higher than 8 or 10 were being tested. An attempt to compare taste values (pT) as determined by water chemists with experience in detecting tastes and by others without special training, has shown that some persons are more or less devoid of taste, but, others are, on the other hand, exceedingly sensitive.

In the case of water ordinarily delivered by public water supplies, the writer is of the opinion that taste is a separate and distinct physiological or physical test and that taste and odor in water need not necessarily bear any definite relation to each other except perhaps in a few special cases. Certain substances, especially foods, undoubt-

edly produce sensations of both taste and odor. The particular taste involved in this electrolytic investigation was a typical metallic astringent after-taste and apparently from most observations had no relation to the odor contained in the water. Incidentally using the water dilution method with a water of high pT value and low pO value, any odor will have disappeared long before any tests are made for taste. It is believed that this method makes it possible to separate the two characteristics under many but not all conditions.

Fatigue in making taste tests is a very important factor. Any attempt to test water of high pT value without dilution will produce fairly immediate fatigue but if one confines his tasting activities to water of low taste concentration in the manner indicated above, some 15 or 20 tastings can apparently be done at one time. To remove the effects of fatigue, several suggestions were tried but apparently a flavorless chewing gum is the most satisfactory. After a time even this becomes ineffective and several hours rest are necessary.

SUMMARY

In the opinion of the writer, the method of pO and pT values devised by Fair is simple and direct and of great value in odor and taste determinations. Improvements in the all-glass nosepiece will render the water dilution method much more sensitive and it is possible that it will still remain somewhat more sensitive than the air-dilution method but not as rapid.

The apparatus and methods proposed are worthy of further investigation with a view toward their future inclusion in the Standard Methods of Water Analysis.

All waterworks operators are much indebted to Fair and Wells for their notable contribution to the subject of odors in water, carrying on the work of the late Professor G. C. Whipple who in 1899 presented the rating of odor intensity now in general use.

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THE OCCURRENCE AND CONTROL OF IRON BACTERIA IN WATER SUPPLIES

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If my experiences in California mean anything with respect to conditions elsewhere, there is good reason to believe that the organisms known as iron bacteria are found in water supplies more frequently and cause more trouble than is generally recognized or suspected. Ground waters in particular are susceptible to infection. Of the 19 well supplies in the company system, no less than 9 have been affected by various members of the iron bacteria family, the trouble in some being local and mild and in others general and severe. As a result thereof it has been necessary to make a careful study of these organisms in the laboratory as well as in the field, attention being directed especially to the factors of practical importance involved in their identification, their characteristic effects on quality, and methods of treatment required for their control.

TYPES AND GENERAL EFFECTS OF IRON BACTERIA

The title of iron bacteria is assigned to the group of organisms capable of withdrawing iron from the water in which they live and of depositing it in the form of ferric hydrate on or in their mucilaginous surfaces. Opinions differ as to the method whereby iron is taken from solution. Some maintain that the withdrawal and subsequent deposition are necessary stages in the vital processes, while others claim that the action is purely chemical and is incidental rather than essential to the life of the organisms. As a matter of practical importance, however, it makes no difference which is correct, for our interest lies in the material which is produced and not in the exact nature of the reaction. This is because the most severe of the troubles attributable to iron bacteria in water supplies are those brought about by the precipitation and resultant accumulation of ferric hydrate.

Before introducing the various members of the family, attention should be directed to their effects when established in a water supply.

In the first place, their growth and development in large quantities are manifested in the distribution system by turbid and discolored water, and in reservoirs by flocculent masses adhering to the walls and floating in the water. Their presence may also be the cause of offensive tastes and odors, although troubles of this sort are usually confined to severe infections and are believed to be caused by the decomposition of organic matter contained in the dead bodies and encasing gelatinous sheaths of the organisms. Still another effect is that brought about by attachment of the growths to iron pipes and the consequent formation of deposits which decrease carrying capacities and which frequently cause the clogging of ordinary house services. In short, there is nothing very pleasant about the iron depositing bacteria. When well established in a water supply system they mean grief and plenty of it.

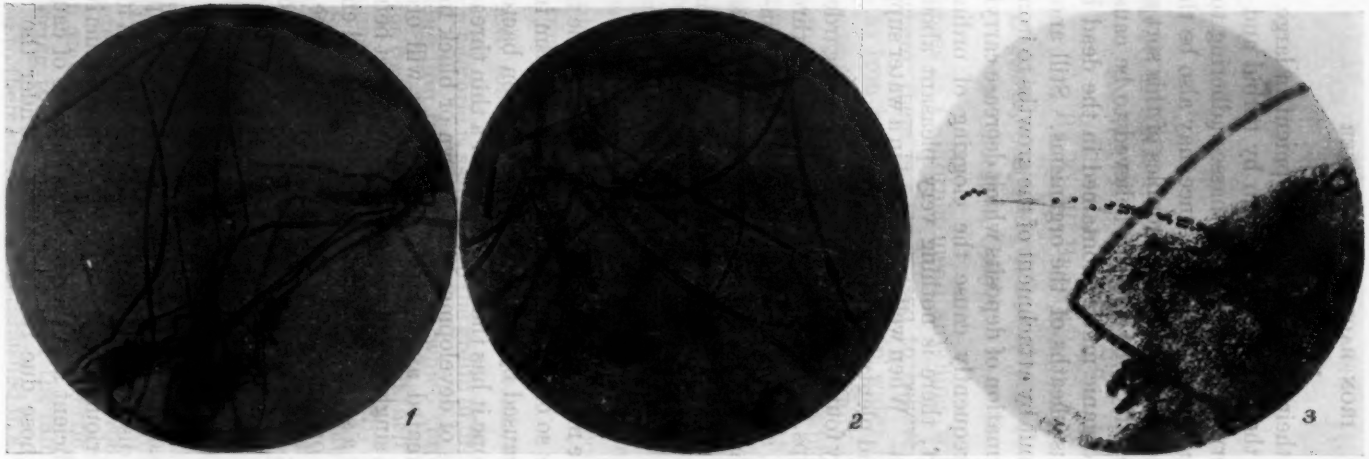
Those commonly found in natural waters may be regarded as divisible into two groups, the first of which includes the thread-like or filamentous forms, and the second the lower forms of iron-depositing bacteria. Members of the filamentous group, which is the most significant from a water works point of view, are Crenothrix, Leptothrix, Cladothrix, Gallionella, and Spirophyllum.

Crenothrix

Crenothrix is the most important representative of the filamentous group because it is so often the predominating organism in dirty and discolored water caused by the development of iron bacteria. Seen under the microscope it has the appearance of a thin thread, colorless in the early stages of development and brown or black in maturity. When properly treated and stained, Crenothrix will ordinarily be found to contain a single row of cells, the general effect being that of a glass tube holding a series of short blocks with rounded ends. In its mature form the organism loses its tubular appearance, becoming wider at the apex and expelling therefrom a multitude of spherical conidia or spores.

Leptothrix

Leptothrix, the second member of the filamentous group, is perhaps even more widely distributed then Crenothrix, although it is not considered to be as serious a trouble-maker. Its reproductive facilities seem to be less efficient and therefore less capable of causing conditions as bad as those due to Crenothrix. Under the microscope,



CRENOTHRIX CRENOTHRIX CRENOTHRIX

FIG. 1

Leptothrix appears as a transparent, tubular thread in early stages, older growths acquiring coatings of ferric hydroxide which have to be removed before the organism can be identified. The threads are naturally straight, but curved forms are not uncommon and none of them show a definite cellular structure.

Cladothrix

Cladothrix is an organism closely related to but not as troublesome as Crenothrix. The relationship is based on the fact that both contain a series of cells enclosed in a gelatinous sheath, the difference between the two being in the greater length of the Cladothrix cell and in the methods of reproduction. For practical purposes, it is merely necessary to know that a comparatively long cell means Cladothrix rather than Crenothrix.

Gallionella

Less frequently found in large numbers, although commonly present in natural waters, are Gallionella and Spirophyllum. The two species are closely related, so much so that it is difficult to distinguish one from the other when they are present in the adult, iron-encrusted form.

Gallionella is characterized by its tendency to form spirally wound threads comparable in their appearance to the effect obtained by twisting the two ends of a hairpin around each other. In some instances the twisting is loose, in others tight, and in older individuals indistinguishable because of iron deposited between the loops as well as on the thread itself. It is thus that the mature form acquires an appearance similar to a string of beads.

Spirophyllum

Last of the filamentous group is Spirophyllum. This organism is characterized by an absence of cellular structure and by a flat band-like appearance, the band being twisted spirally about the longer axis. Here also the twisting effect is varied. In some it is loose, but in others it is very close and therefore similar to the tightly twisted threads of Gallionella. All of which explains why the two species are alike in appearance and why one is often mistaken for the other.

Bacillus forms

The lower forms of iron bacteria must also be considered. It is now agreed that practically all natural waters contain organisms of the

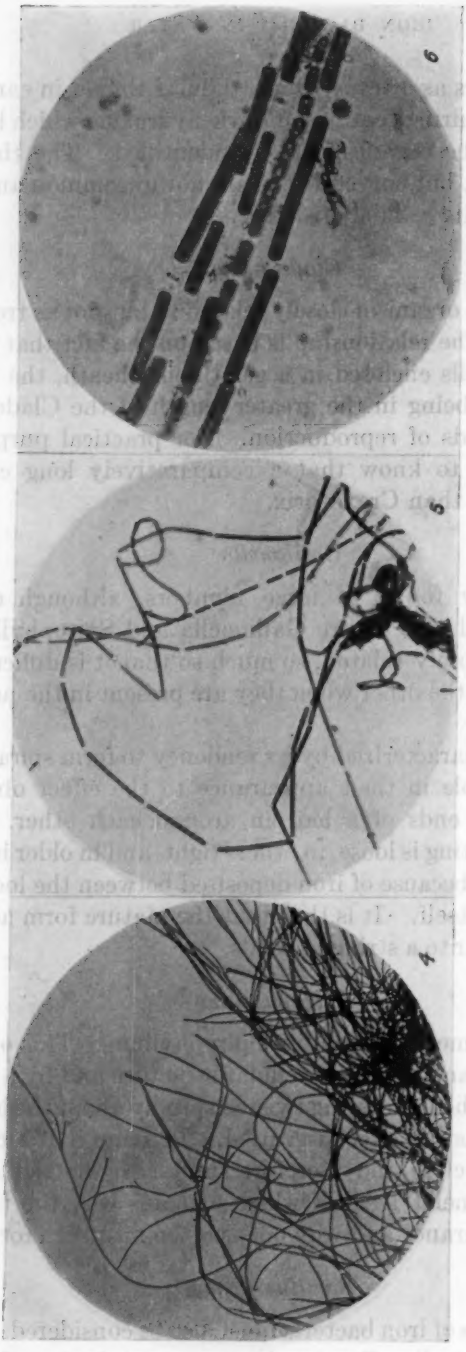


FIG. 2

bacillus type which are capable of precipitating iron in one form or another from solutions of certain organic iron salts. It is further agreed that these organisms are not iron bacteria proper in the sense that they require iron in solution for their development. It appears rather that the iron salts provide needed food and that ferric hydroxide is thrown out of solution as a waste product. Organisms of this kind have been found in several of our supplies and have been grown as pure cultures in order to study their various characteristics. Under the microscope the majority of them appear in the form of a bacillus which has a length of 2.0 micra and a thickness of 0.4 micron. Another type, of which only a superficial examination has been made, is about twice as big as the bacillus and is somewhat ellipsoidal in form.

Sulfur bacteria

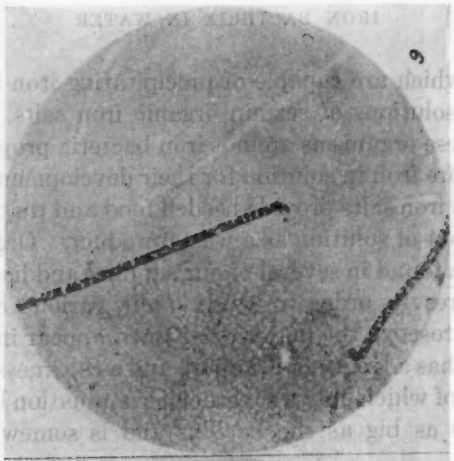
Still another group of organisms capable of throwing iron out of solution is found in the sulphate reducing bacteria and the hydrogen sulphide forming bacteria. They are commonly present in decaying organic matter and are known to cause the precipitation of iron as ferrous sulphide. In water supplies their most important representative is Beggiatoa alba, which is a long thread-like organism of tubular form, uniform thickness, and rounded ends. Its outstanding characteristics consist of motility, as exhibited by slow jerky movements at the ends, and the presence of sulphur granules within the sheath. In mass growths it appears as a dark gray, loosely textured, felt mat and may be found in reservoirs adhering to the walls and bottom. Its growth and development are almost invariably followed by complaints about malodorous and discolored water.

METHODS OF IDENTIFICATION

Collection of samples

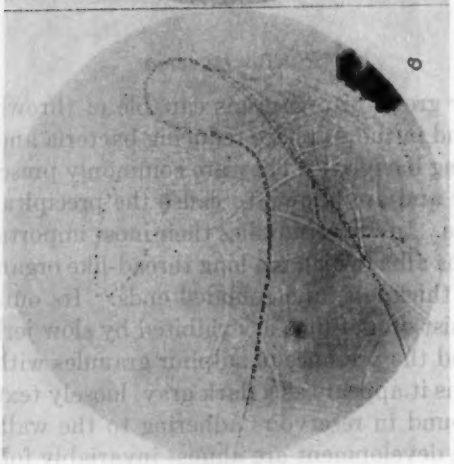
For practical purposes nothing is more important than a knowledge of how to find and identify the various types of iron bacteria. The problem is comparatively simple when examining well developed specimens present in dirty water, but it is not so easy when searching for sources of infection due to the fact that samples from suspected wells may be perfectly clear and may in no way suggest the presence of iron bacteria. In such instances filtered samples are of no avail and it becomes necessary to use either or all of the following methods:

1. The first method is that of filtration through a Berkefeld filter.

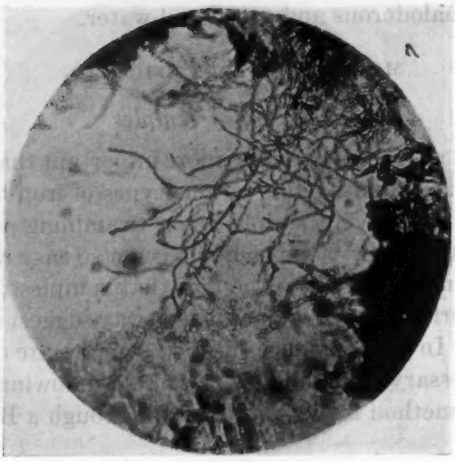


Beggiatoa

Fig. 4



Beggiatoa



Gallionella

Fig. 3

This is generally provided for by connecting a filter to a well pump discharge and allowing it to stay in place for a week or ten days. Water passing through the filter during that period leaves on the porcelain core a dark brown mud, portions of which can be examined for the presence of iron bacteria.

There are two objections to the filter method. In the first place, it cannot be used on low lift pumps because fairly high pressures are needed to force water through the porcelain core. This means that filters are of no use in investigating wells pumping into a reservoir under a low head. Secondly, misleading results are likely unless care is taken to see that there is no possibility of back flow in examining a well pumping directly into a distribution system. By this I mean that the filter must be connected to the pump side of a check valve.

2. Ideas as to infected wells are sometimes obtained by examining material scraped from the covers of check valves on the pump discharge lines. This method is useful on wells that are pumped into a reservoir and not directly into the distribution system.

3. Probably the best method for general and really reliable use is that of collecting a sample in a sterile bottle from a suspected well and allowing it to stand at room temperature for a week or ten days. If the well is infected with iron bacteria, their presence is indicated by the formation of white or brown colored deposit, microscopic examination of which furnishes definite information concerning the identity of the organisms. It has been found in our work along this line that gallon samples give the best results, although there is no obvious reason why smaller ones should not be just as satisfactory.

Staining of specimens

With proper samples available and with an idea as to the appearance of the various organisms, it next becomes necessary to know what can be done to facilitate their identification under the microscope. The following suggestions will be helpful:

1. So far as Leptothrix, Cladothrix, and Crenothrix are concerned, their structural features can best be demonstrated by treating the coated threads with 1:2 hydrochloric acid and then using iodine to stain the uncovered membranes. To do this the material to be examined is first placed on a microscope slide and covered with a coverslip. Acid is then applied to the edge of the coverslip and sucked through the water between the coverslip and the slide by

placing a small piece of filter paper on the opposite edge of the coverslip. Iron deposits are thus dissolved, leaving the membranes ready for staining by applying iodine in the same manner as the acid. Specimens so prepared will produce in many instances a striking picture of the structural features of the organisms. Analine stains such as gentian violet and carbol fuchsin are useful but none of them compare with iodine in bringing out the sheath and cellular characteristics of Crenothrix and Cladothrix.

2. The acid and iodine method is unsatisfactory for Gallionella and Spirophyllum because the threads of these organisms are delicate in composition and are therefore less resistant to the action of dilute acid. Fair results are obtained occasionally by staining a carefully fixed specimen with carbol fuchsin, but for the most part it is best to rely on unstained preparations when looking for the twisted effects which are characteristic of these organisms.

3. Ordinary methods of mounting and staining are satisfactory for the bacillus forms. Of the stains that have been tried carbol fuchsin seems to give the best results and is believed to be as good as any for use with the lower forms of iron precipitating organisms.

LABORATORY STUDIES

I have already mentioned the fact that the iron bacteria family has been the subject of a comprehensive laboratory study. This work has included experiments with artificial culture media, studies of physiological and morphological characteristics, studies of their effects in relation to the quality of water, and experiments to determine the lethal doses of chlorine and chloramine. The results may be summarized as follows:

1. Efforts to obtain pure cultures of the filamentous forms were generally unsuccessful.

2. Pure cultures of the bacillus form were isolated and examined. This organism was shown to be the cause of precipitation in tubes of broth[1] made up of tap water, proteose peptone, iron ammonium citrate, and manganese carbonate. Tubes inoculated with pure cultures showed complete precipitation in four days, whereas there was no action in control tubes incubated for the same period.

[1] Proteose peptone	1 gr.
Iron amm. citrate	2 gr.
Sat. sol. $MnCO_3$	100 ml.
Tap water	900 ml.

3. Material precipitated in broth tubes inoculated with tap or well water turned black after standing ten or twelve days. On the other hand, the precipitate in tubes inoculated with pure cultures of the iron bacillus remained unchanged even when incubated for several months. The difference between the two is of practical importance in that it indicates the presence of sulphur bacteria, the activities of which produce hydrogen sulphide and convert ferric hydroxide to ferrous sulphide. This means that the most troublesome of the iron bacteria infections, particularly with respect to taste and odor production, are those accompanied by organisms which are capable of throwing iron out of solution in the form of ferrous sulphide.

4. Interesting results were obtained from a series of experiments with gallon samples of well water. To begin with, three samples were collected in sterilized gallon bottles, the water at the time of collection being perfectly clear and without taste or odor. Of these, one was left as collected, one was sterilized in an autoclave and inoculated with a pure culture of the iron bacillus, and one was sterilized and set aside as a control. All were then allowed to stand at room temperature for about a week. After this period it was found that there was a lot of flocculent material in the raw water and in the sample inoculated with the bacillus, whereas the sterilized water remained clear and unchanged in appearance. Examination of the flocculent material showed the same bacillus form in both samples.

The next step consisted of adding H_2S producing bacteria to the sterile sample and also to the one inoculated with the iron bacillus. Both were then allowed to stand for several days, after which it was found that hydrogen sulphide was formed in the bottle containing the iron-depositing bacteria and that there was no change in the sterile water. It thus appears that H_2S is formed by organisms which feed on the iron bacteria, and that the presence of such organisms explains why some infections are productive of disagreeable tastes and odors.

5. Attempts to isolate bacteria responsible for the formation of hydrogen sulphide were not altogether successful. Examination of impure cultures again indicated that the predominating organism was a bacillus. This time, however, it was somewhat longer and thinner than the iron bacillus and occurred for the most part in chains or filaments made up of several rods joined end to end.

A more satisfactory result of this work was the development, after experimenting with about twenty different media, of a culture

medium[2] which makes it possible to identify waters containing the hydrogen sulphide organisms. The technique is simple and involves nothing more than adding 10 ml. of the water in question to a tube of broth, incubating at 37°C. for two or three days, and waiting for the production of hydrogen sulphide. Presence of the latter is indicated by the characteristic blackening of lead acetate paper inserted in the tubes under the cotton plugs.

6. The final job in the laboratory consisted of determining the doses of chlorine and chloramines required to control the various organisms. Over two hundred tests were made, yet I am unable to furnish very much in the way of definite and usable information. In general, it can be said that the filamentous forms of iron bacteria are destroyed by a chlorine or chloramine residual of 1.0 p.p.m., and that residuals twice as large are required for control of the lower forms. In all cases it appears that there should be a contact period of at least four hours.

METHODS OF CONTROL

Before discussing available methods of control, I wish to make it clear that my remarks will apply in particular to systems which are not equipped for filtration or iron removal. This is because iron bacteria are capable of thriving in waters which contain less than 0.1 p.p.m. iron, and because low iron contents are characteristic of the supplies with which I am familiar. There has thus been no need on my part to think about the comparatively expensive remedies of filtration and iron removal.

Copper sulphate

Early methods of treatment involved the use of copper sulphate. In some instances this chemical was applied intermittently, and in others continuously, to collecting reservoirs. It was also applied occasionally in large quantities directly to wells which were known or suspected sources of infection. As a whole, the results were nothing more than fairly satisfactory. Conditions in the treated wells appeared to improve for short periods thereafter, but water in reservoirs never seemed to have the necessary degree of clarity and freedom

[2] Beef extract ..... 1 gr.
Peptone ..... 2 gr.
Lactose ..... 2 gr.
K_2HPO_4 ..... 0.5 gr.
Distilled water ..... 1000 ml.

from bacterial life. To put it briefly, the use of copper sulphate for the control of iron bacteria is not recommended.

Chlorine

Straight chlorination may or may not be successful. It does quite well where there is a reservoir available for a suitable contact period and where the residual entering the distribution system is not excessively high. On the other hand, chlorine in any quantity is likely to be disagreeable if it combines with organic matter naturally present in the water or in deposits lining the distribution pipes. Woeful effects are possible in either event. Chloro-organic compounds are productive of what consumers describe as a medicinal flavor, and as such they cause as much if not more trouble than conditions brought about by the iron bacteria. Two of our supplies have been affected with this sort of thing. In one it was due to oxidizable organic matter present in one of the wells, and in the other to organic matter present in the mains. The former resisted all kinds of treatment and was only corrected by abandoning the well, while the latter was remedied by changing the type of treatment.

Barring complications in the way of tastes and odors, chlorine is an effective agent for the control of iron bacteria. As a general rule, application to the inlet of a collecting reservoir is to be preferred, although there are times when it is possible to obtain satisfactory results by application to a pump which discharges directly into a distribution system. The dose ought to be fairly close to 1.0 p.p.m., but it usually has to be modified where direct application is unavoidable.

Ammonia and chlorine

Treatment with ammonia and chlorine appears to be an uncertain proposition. Although others have reported excellent results and have attributed them to the formation of a persistent residual, my experiences with ammonia and chlorine in handling iron bacteria infections have not been encouraging. The combined treatment has been tried at three plants, but in none of them has it been possible to establish an effective residual with anything like normal doses, despite all kinds of variations in the way of ratios and points of application. Furthermore, doses large enough to carry a residual into a system have invariably been followed by numerous complaints about chlorinous tastes and odors. All of which accounts for my tendency

to favor chlorine alone as compared to ammonia and chlorine combined when it comes to controlling the development of iron bacteria.

On the other hand, satisfactory results have been obtained with chlorine and ammonia in the treatment of waters unaffected by iron bacteria. This is especially true of surface supplies, residuals in these forming as easily as the well advertised "falling off a log," and persisting even longer than might be expected. It would be interesting to know why it was impossible to duplicate this effect in each of the three well supplies where I attempted to use ammonia and chlorine for the control of iron bacteria.

Chlorine and sulphur dioxide

The most successful and altogether satisfactory method of control is that of chlorination at a reservoir inlet followed by dechlorination with sulphur dioxide at the outlet. To provide for this type of treatment, it is necessary, of course, that the supply consists of wells pumping into a collecting reservoir, and that the reservoir be of sufficient capacity to assure an adequate period of contact for the chlorine and water. Chlorine can then be applied to the incoming water at a rate sufficient to destroy the iron bacteria, and the residual at the outlet can be removed almost instantaneously by treatment with sulphur dioxide. Application of the latter through a direct feed chlorinator or ammoniator to the suction side of a booster pump is a convenient arrangement.

The chlorine dose should be not less than 1.0 p.p.m. and the contact period should be 4 hours or longer. For those who are interested in the process, one part of chlorine is equivalent to 0.92 parts of SO_2, although it will probably be found that efficient dechlorination requires about 1.15 parts of SO_2 to one part of chlorine.

The most convincing example of what can be accomplished by chlorination and dechlorination is to be found in the system which got into trouble due to the combination of chlorine with organic matter in the mains. After finding that ammonia in no way affected the medicinal flavor, I decided to try chlorination at the inlet and dechlorination at the outlet of the collecting reservoir. Satisfactory results were quickly obtained. At this time the water in the reservoir is perfectly clear, there is little or no trouble with iron bacteria in the mains and services, and there are no longer any complaints about chlorinous tastes and odors.

SUPPLEMENTARY METHODS

Besides methods of treatment which are applicable to sources of supply, there are others of a supplementary nature which are helpful in avoiding troubles in distribution systems. The most effective of these are as follows:

1. Flushing is the cheapest way to get rid of loosely adherent or suspended material, and as such it is an indispensible part of the control program. In fact, systematic flushing of dead ends and areas of restricted circulation is in itself sufficient to avoid troubles brought about by mild infections.

2. A comprehensive main sterilizing program is helpful in many instances, especially where a system has become fairly well loaded with loosely deposited material. Chlorine for this purpose can be applied by means of a standard main sterilizing outfit, or by heavy dosing of well pumps which discharge directly into a distribution system. It should not be expected that a single application of chlorine is all that is needed. On the contrary, severe cases call for repeated doses and thorough flushing.

3. Main cleaning is effective, providing adequate arrangements are made for treating the sources of supply, as cleaning in itself is too expensive unless it is certain that further seeding of the system is being prevented. We have used two methods, the first and least useful of which is that of blowing out small pipes with compressed air. The second is that of pushing a tool through the sections to be cleaned, the material so loosened being washed out by a continuous flow opposite to the direction of the tool.

4. If consumers' reactions mean anything, a lot of good has been accomplished by pumping out partially clogged services with strong hyyochlorite solutions. Office buildings as well as homes have been treated in this manner, practically always with gratifying results. The procedure is simple and involves nothing more than disconnecting a service, pumping in hypochlorite by means of a hand operated force pump, and thorough flushing after allowing the chemical to remain in the pipes for at least two or three hours.

SUMMARY

It is desirable in closing to consider very briefly the steps involved in solving the problems arising from the presence of iron bacteria in water supplies. These are:

1. Find the sources of infection and identify the organisms therein. Gallon samples which have been allowed to stand for several days are the best for this purpose.

2. Provide for chlorination if the infection and the results thereof are sufficiently severe. Chlorine applied to the inlet of a collecting reservoir followed by dechlorination at the outlet is the most satisfactory method of control.

3. Supplement control at the sources of infection by well planned flushing and main sterilizing.

There, in a nutshell, is the solution to the iron bacteria problem. Do not look for immediate or spectacular results. Expect rather that progress will be slow, bearing in mind the fact that even the most obdurate and well established growths can be controlled by the methods of treatment that are now available.

DISCUSSION

FRANK E. HALE (*Director of Laboratories, Department of Water Supply, New York, N. Y.*): The paper by Kenneth W. Brown is exceedingly interesting and undoubtedly advances our knowledge of the iron bacteria, particularly in methods of identification and culture. There are a few points I should like to mention.

(1) It has usually been stated that Crenothrix grows best in the dark and in the absence of oxygen. Apparently in Mr. Brown's experience it grows well in open reservoirs and this would seem to be at times the source of the organisms since superchlorination followed by dechlorination of water in the reservoir has prevented trouble in the mains. By this procedure no chlorine would be active in the mains to prevent growth. I assume that this result was preceded by clearing the mains first. We have had similar experience in that growth was found to flourish in the open air on a concrete apron onto which water was wasted from a well system.

(2) In our experience hydrogen sulphide and absence of nitrate is associated with deep wells. It would therefore seem probable that anaerobic bacteria are responsible, obtaining oxygen for their growth by reduction of sulphate and nitrate in the absence of air. Mr. Brown had difficulty in isolating sulphate-reducing bacteria. He does not state whether he tried to isolate anaerobic cultures.

(3) The dosage of chlorine required is far in excess of results elsewhere. Monfort at St. Louis found 0.5 p.p.m. effective either as

chlorine or chloramine. In our own experience trouble has apparently been avoided by less dosage although continuously applied. Also jelly growths in wells or condenser water have been controlled elsewhere by as low as 0.3 p.p.m. chlorine.

In our experience not only do Crenothrix-type organisms cause trouble, but also various fungi, such as Saprolegnia, Achlya, and Penicillium. When branching filaments, with amorphous foliage-like appearance, with round bodies either colorless or granulated, are present we suspect fungi and search for other identifying characteristics. The introduction of Electrolux refrigerators has called attention to these problems in recent years by the clogging of the screens in the cooling water supply. The New York Water Service Corporation in Flatbush and the Jamaica Water Supply Company in Jamaica have both been troubled. Spirophyllum has been identified, also Gallionella. Growths have also occurred in the large risers in apartment buildings and been cleaned out by hypochlorite solution in the manner indicated by Mr. Brown. Mains have also been treated at night with 1 p.p.m. chlorine and thoroughly flushed. However, continuous chlorination with residual less than 0.2 p.p.m., preferably less than 0.1 p.p.m. from standpoint of taste, has certainly resulted in great reduction of complaints.

It seems probable that the introduction of gravel wells of the Layne-type may have been partly responsible for this increased trouble in the last few years. Gravel is introduced from the surface deep into the ground surrounding the bottom of the well. Also they are open at the surface around the pump. In at least two instances in the Jamaica district we have found the organism growing on the iron plate at the top of the wells and the return of cooling water from the electric motors over these surfaces offers a good chance to introduce and to continue such growths. Such surfaces are now being washed with hypochlorite solution and the well water continuously chlorinated with low residual. Apparently this has remedied or at least greatly reduced complaints of clogging of Electrolux refrigerators.

We have had at least two experiences with Achlya on our Long Island watershed. The growth appeared at one well station in masses at the pump. The individual wells were treated with about two pounds of copper sulphate and the growth became detached in such amount that it stopped the pump. It appeared again a few months later as only certain wells had been treated. There has been no further trouble after a second treatment including more wells. The

same growth appeared at Massapequa infiltration gallery. The growth masses gathered on the screens at Milburn Pumping Station several miles down the conduit. Treatment of the pump well at Massapequa continuously with 0.6 p.p.m. chlorine cleared up the growth completely so that none is now visible. This dosage produced a slight residual chlorine, 0.03 p.p.m., at Milburn. Some of the growths have produced only an earthy or musty odor but others, probably of the Crenothrix family, have produced very foul odor when masses have been kept a few days in a covered jar. Dark brown, almost black, masses may be due to Crenothrix manganifera described by Jackson many years ago. This would not require iron in the water. I note that very low amounts of iron were present in some of the waters giving trouble in Mr. Brown's district.

REPORT OF FILTERING MATERIALS COMMITTEE[1]

In the present state of our knowledge of the filtration process observations made on operating filter units are most likely to yield information of immediate practical value. To obtain coördinated observations of this nature the filter materials committee, through Mr. W. M. Wallace, has questioned a number of filter plants throughout the country as to the behavior of filter beds. Specifically, the inquiries referred to the size and grading of sand being used, depth of bed, rate of filtration, depth of floc penetration observed and condition of sand. In addition, information was requested on any unusual filter materials being used or studied.

A number of replies were received, including those from Wyandotte, Flint, Midland, Mt. Clemens, Grosse Pointe Farms, Saginaw, Highland Park, and Grand Rapids, Mich., and Cleveland and Cincinnati, Ohio. Seven of these plants reported on the depth of penetration of floc, in some cases giving concurrent data on sand size and filtration rate. These data are shown in table 1.

It is interesting to note that 5 of the 7 plants report penetration of less than 3 inches, and that the penetration at Cleveland is reported to be of the order of $\frac{1}{16}$-inch or less. The greatest penetration reported is 10 inches. It is unfortunate that the data on sand size and filtration rate are not sufficiently complete to make evident any correlation between these factors and floc penetration. Rates of filtration reported range from 103 to 155 m.g.d. per acre and sand size from 0.25 to 0.50 mm. effective size.

Reports of the condition of the sand beds have been received from five cities, three of which make available also the data on how the beds are washed. Wyandotte, reporting good sand condition, attributes that result to the practice of prechlorination and preammoniation, at 0.8 and 0.25 p.p.m. respectively. The wash rate at this plant varies from 34 inches per minute at the beginning of the wash to 27 inches at its close. Flint, reporting good condition in winter and

[1] The members of the Committee are: F. W. Herring, *Chairman*, W. Wallace, J. W. Armstrong, J. R. Baylis, G. M. Fair and M. E. Smith.

Mr. James W. Armstrong was not in agreement with the report and hence did not sign it.

bad in summer, washes at the rate of 18 to 20 inches per minute. Cleveland, reporting good conditions, washes at 24.6 inches per minute in mid-winter and gradually increases the rate to 36 inches per minute in mid-summer. In this connection, also, Mt. Clemens states that the formation of small mud balls was checked by raising the

TABLE 1

Data on floc penetration and filter condition

CITY	FLOC PENETRATION, INCHES	SAND SIZE, MM.	FILTRATION RATE, M.G.D. PER ACRE	SAND CONDITION	WASH RATE, INCHES PER MINUTE
Wyandotte	4–7	0.45	103	Good	34–27
Flint	2–3		125	Good in winter; bad in summer	18–20
Midland	2			Good	Maximum with 30-inch freeboard
Mt. Clemens	1	0.50		Small mud balls	
Grosse Pointe Farms	10				
Grand Rapids		0.25		Bad	
Cleveland	$\frac{1}{32}$–$\frac{1}{16}$	0.39	125	Good	24.6–36.0
Cincinnati	2	0.37	155		

washwater troughs and using a higher sand expansion. Further, the reply from Grand Rapids, in part, is as follows:

"Mud-ball formation, cracking, etc. gives us lots of trouble here due almost entirely to inefficient washing. The underdrain system of 15 of our 20 filters is the ridge and furrow type having perforated bronze plates in the bottom of the furrow. The tiny holes in these plates become plugged with hard deposits of lime carbonate. In my opinion, this type of underdrain is a calamity where water contains high normal carbonates or caustic alkalinity. Since wash water cannot get through the plates, that section of the filter cannot be washed. Mud deposits and cracking results. Seven of this type filter have been overhauled since I have been here. In all, sand was found mixed with the gravel even down to the underdrain. There was very poor stratification of gravel. Our only means of removing mud balls is to renovate the filter, cleaning out the underdrain plates."

The Cleveland report on sand condition contains the following statement:

"In observing the condition of the filter beds, I find the sand in a very clean condition, free from organic incrustation; but the bed has a considerable number of small, soft mud balls, averaging in size about ¼ inch in diameter. There seems to be practically no cracking, only at the point around the filters where the sand is up against the side wall, and that shows up only when the bed is drained. There are mounds of sand not over 6 inches in height, in possibly four or five places in the filters next to the side or end walls. These mounds are soft and caused by the imperfect washing due to reduced pressure at the ends of the laterals in our manifold system. I have been draining the filters about once a month, and digging around the sides and ends of the filters for a width of 15 to 18 inches, and for a depth of a foot or so, and throwing this sand in the center of the bed. I believe this will eventually reduce the small mounds, and to destroy the small, soft organic mud balls. I believe chlorinating the wash water will help considerably. These mud balls consist mostly of aluminum hydroxide, organic matter and clay, with a sand grain or two as a nucleus."

Among the cities listed, anthracite coal as a filter material is being studied at Flint and at Grand Rapids. At the latter plant, a softening plant, it has been observed that "The effluent produced by the anthracite was equal in clarity to that produced by the sand, and we have noticed no incrustations of lime on the particles of coal."

An extended memorandum on observations at Richmond has been prepared by Mr. Marsden C. Smith, of Richmond, Va., a member of this committee. At Richmond it has been possible to compare the performance of 1,078-square foot filters with that of 2-inch glass-tube filters, under various conditions of filtration rate and sand size. The following remarks are quoted from this memorandum:

"A factor, which for ease of expression, may be called "Filterability Factor," determines the filtration results. No chemical or physical analysis of water known to us permits a determination of this factor or, in other words, a prediction of the filter operation.

"The rate of filtration, of course, affects the length of the run, the percent of water used for washing and the quality of the effluent. But this cannot be determined from any known analysis of the water onto the filters; for example, a filter may actually run more hours when operating at 3½ than at 3 m.g.d. and at the same time more than one being operated at 4 m.g.d. The total quantity filtered may vary in the same manner. But almost always the slower rate of filtration produces a superior effluent when there is an observable difference. This is no doubt largely due to different distribution of filtered materials in the sand, which is in turn due to the rate of filtration.

"Flocculated material has never been drawn through a 30-inch depth of 0.45 mm. effective size sand when the available loss of head is limited to 5 feet as at Richmond; thus the run is terminated by rate decrease.

"Flocculated material has been drawn through a 24-inch depth of

0.63 mm. effective size sand at from 2 to 3 feet loss of head. Hence, on some runs with this sand the run is terminated by rate; at other times by filter effluent quantity.

"Various methods of washing the filters have been tried including starting at a very low rate for the purpose of loosening the waste materials followed by a higher rate; at lower wash rates for a relatively long time and at higher rates for a relatively short time. The most efficient wash method is difficult to accurately determine. However, we are of the opinion that the most economical method is to wash at the maximum rate possible to avoid loss of sand, unless the water going onto the filters is so poorly prepared that a much lower rate is required.

"Great caution must be exercised in predicting the behavior of plant-size units from observations made on the 2-inch glass filters. Parallel runs with the same sand and water as plant filters may give widely different results from the plant filters, particularly in the initial and the increase in loss of head. This is probably due to the difficulty in controlling the rate through such a small area of sand sufficiently close for the results to be expressed in the relatively enormous area of the plant filter. Further, there is an appreciable temperature rise in the glass filter when the water is cold and the filters are in a warm room. Some runs have been obtained with closely parallel results, but other runs made with *equal care* and *with* the *same apparatus* and *personnel*, with widely different results. The great difference in the ratio of area to periphery existing between the plant and experimental filters, must have its effect."

EXPERIMENTS ON PENETRATION

Some extremely interesting observations have been made on the penetration of floc by Mr. James W. Armstrong, a member of this committee. Mr. Armstrong has conducted a number of experiments on glass-tube filters, each equipped with sand of a uniform size. Experimental method consisted of passing coagulated water through the filter until the loss of head reached 8 feet or the effluent showed a turbidity of 0.02 p.p.m. The sand was then carefully removed in ½-inch thicknesses and the adhering floc washed off in a jar of water. The amount of floc retained by each thickness was determined by measuring the turbidity of the water in the jar. In general, it may be said that the experiments made to date indicate that under these conditions practically no floc passes beyond the depths given in the following table:

Sand Size, mm.	*Penetration, inches*
0.37	3
0.43	3
0.50	4
0.60	7
0.76	10

SAND BED HYDRAULICS

It is obvious that in its fundamentals, the filtration problem is one of applied hydraulics. Prof. Gordon M. Fair, of this committee, has prepared a concise statement of the present state of our knowledge of the hydraulics of filter flow. Prof. Fair's résumé is appended to this report. In brief, he states that we have made considerable progress in defining in quantitative fashion the effects of the various factors involved in the loss of head attending the passage of clear water through a bed of granular material. A number of investigators have attacked this problem, from the time of Allen Hazen's work on slow sand filters to the most recent work of Fair and Hatch. It has now been demonstrated that loss of head through a rapid filter can be formulated only in terms of the entire grading curve, and that it is proportional to the depth of the bed, the rate of filtration, the viscosity of the water, the square of a sand-shape factor, and to a porosity factor which can be expressed as $\frac{(1\text{-Porosity})^2}{(\text{Porosity})^3}$. For each increment of sand depth, loss of head is inversely proportional to the square of the grain diameter. The sand-shape factor can be determined with reasonable accuracy by inspection of the grains under the microscope.

Prof. Fair recommends that the following problems be given further attention by research students:

1. Determination of surface area of particles.
2. Effective area or void volume through which flow takes place.
3. Effect upon the resistance to flow of coatings on the grains.
4. Some standard method of reporting the dirtiness of sand.
5. What takes place during the filtration of water.
   (a) Is the sand merely to support the floc.
   (b) Is it harmful to permit the floc to penetrate the bed to appreciable depth. If not, does this increase the efficiency of the bed by longer contact of water and floc.
   (c) Is it practical to use coarser sand and thereby perhaps increase the length of the filter runs.
   (d) What quantities of floc should be allowed to reach the filters to ensure good filtration.

It is apparent that a subject of great complexity is disclosed by a study of the filtration process. The problem of setting up in any detail the most desirable attributes of a filter bed is beset with difficulties. These arise, first, from the great number of factors entering

into the over-all efficiency of a filter, and, second, from the fact that a number of the more important ones are not susceptible to direct measurement by any means now known.

To begin with, we may say that the most satisfactory filter material will, while yielding a clear effluent at all times, require the least expenditure of energy, as made evident by hydraulic losses. In other words, it is the material that gives the longest period of service under given circumstances of available head, rate of filtration and condition of coagulated water. Further, it must be capable of being kept in good operating condition with the least amount of effort.

It is easy to see that a sand that is too coarse will fail by allowing foreign material to pass through the filter after but a short period of service. It is equally obvious that a sand that is too fine will introduce hydraulic losses that are unreasonably high. But to determine the optimum point between these two extremes is by no means any easy task. Further, the significance of slow or rapid grading of particle sizes from fine to coarse is but imperfectly understood. Bed depth also is most certainly a factor in filter performance and there obviously is some depth beyond which there is no need of going.

The factors so far mentioned are easily measurable. But what of grain shape? Is a sharp-grained sand to be preferred to a round-grained sand? Roundness or sharpness can be measured accurately only with extreme difficulty. And, of utmost importance, what measurement can be made that will define the filterability of coagulated water? It is not inconceivable that variations in this one factor, due to capricious changes in the raw water, may overshadow the effects of variations in all other elements in the phenomenon and therefore greatly limit the sphere of rationality in the filtration problem. Nevertheless, even here, just as we refuse to surrender to the vagaries of rainfall phenomena, but measure frequencies and intensities and apply statistical methods to a run-off problem, we may at some time be able to go beyond rule of thumb in dealing with the complex problem of filtration.

APPENDIX

MEMORANDUM FOR COMMITTEE ON FILTERING MATERIALS

By Gordon M. Fair

(*Harvard University, Cambridge, Mass.*)

In the study of the hydraulics of filtration most of the previous workers have placed considerable emphasis upon determining some measure of particle diameter which would reveal the hydraulic characteristics of a sand bed as a whole. Such a diameter was usually found to be a hypothetical quantity which was made to account for two or more of the complex variables entering into the problem. These measures of sand size have been diffused in terms of a percentage value usually referred to spheres.

Recently, however, workers in this field have been endeavoring to insert into the sand flow equation the effect of particle size and shape in terms of the surface area of sand, producing resistance to flow. In this way they are more able to analyze the individual variables and attach to each one its proper significance.

FILTRATION

One of the most widely used formulas for the hydraulics of filter flow is that of Allen Hazen involving the effective or 10 percent size of the sand.

$$v = c\,d^2\,\frac{h}{l}\,\frac{t+10}{60}$$

v = velocity in m/day.
c = coefficient.
d = effective size in mm.
$\frac{h}{l}$ = loss of head per unit depth.
t = temperature in degrees F.

Hazen found that the 10 percent size assumed a value which varied in close agreement with the resistance to flow when confined to certain conditions of size variation and packing. This formula, as designated by its author, should be applied only to unstratified sands whose effective size is less than 1 mm. and whose uniformity coefficient is less than 5. When applied within these limits, it proves to be a

very useful tool. One objection to its use commonly cited is that the coefficient ranges from 400 for dirty, closely packed sand to 1200 for clean, loosely packed sand. This variation may be due in part to the change in porosity but primarily to the surface conditions of the sand grains. This latter factor is difficult to account for in any equation. Hazen's formula has been grossly misused in its application to stratified sands where the porosity is substantially constant regardless of the uniformity of grain size, and to soils of high uniformity coefficient. Slichter's formula $\frac{h}{l} = \frac{K\mu v}{0.2012d^2}$ is one of the first to determine a factor which alone depends upon the porosity of the material, in which respect it represents a step forward from the results of previous workers. In this equation,

$\frac{h}{l}$ = loss of head per unit depth.

K = porosity factor.

μ = coefficient of viscosity.

v = velocity over gross area in ft./min.

d = effective diameter in mm.

The formula is rather impractical in its use since the effective diameter must first be determined by air-flow measures. Substitution of Hazen's effective size into Slichter's equation, as is often done, will yield erroneous results since the former is dependent upon obtaining a definite porosity while the latter already contains a porosity factor K.

Baldwin-Wiseman proposed an equation for the flow of water through sands which in its theoretical development contains fundamental ideas. It is perhaps the earliest attempt to formulate the fundamental factors affecting the hydraulics of filter flow. Some of the factors entering into the equation are a bit hypothetical and are perhaps incapable of direct measurement. Its practical application is therefore limited.

Hulbert and Feben have developed an equation for the flow through stratified sands.

$$l = \frac{24.2\, d\, r(69.43 - p)}{10^5\, s^{1.89}\, (t + 20.6)}$$

l = loss of head in ft.

d = depth of sand in in.

r = rate of flow in m.g.a.d.

p = porosity (% void by Jackson Turbidimeter method)
s = sand size in mm. (median or 50 percent size).
t = temperature in degrees F.

This formula is similar to that of Hazen in that it contains the 50 percent size. The 1.89 power of s is in contrast with the value of 2.0 employed in other formulae. There is reason to believe that when the data published by Hulbert and Feben are corrected to a constant porosity their sand-size effect would agree more nearly with that of other workers.

Fair and Hatch have proposed an equation in which the fundamental factors influencing the hydraulics of flow through sands have been combined into a single dimensionless equation which takes the following form for an unstratified bed,

$$H = K\,L\,T\,F\,v\left[\frac{s}{w}\,\text{Sum of}\,\frac{P}{d}\right]^2$$

and for a stratified bed,

$$H = K\,L\,T\,F\,v\,\frac{s^2}{w}\left[\text{Sum of}\,\frac{P}{d^2}\right]$$

H = loss of head in terms of water column.
K = filtration constant $= \frac{5}{g}$.
L = vertical depth of sand column.
T = temperature or viscosity-density factor.
$F = \frac{(1-f)^2}{f^3}$ = porosity factor; f = porosity ratio of the sand.
v = velocity of approach over the gross area of the bed.
s = sand shape factor.
d = geometric mean of rated sizes of adjacent sieves.
w = total weight of sand analyzed.
P = weight retained between adjacent sieves.

This formula in its generalized form may be applied to any of the usual conditions of sand packing encountered in water filtration, namely, sands uniform in size with uniform voids and sands non-uniform in size with uniform voids in unstratified or stratified beds (slow or rapid filters). The sand-flow equation has its origin in the pipe-flow equation and transformations from one to the other are made primarily on the basis of the surface area in contact with a unit volume of water flowing. This measure which replaces the diameter

of pipe or of sand pores involves, in the case of the latter, a measure of the porosity within the material, thereby making it entirely independent of the arrangement of the particles or the degree of compactness. The sand shape factor may be assigned with reasonable accuracy by inspection of the grains under the microscope or analytically by a measure of the average volume of a few hundred representative grains.

Other formulae involve in their development an analogy to the pipe-flow equation among which are the equations of Blake, Burke and Plummer, Chilton and Colburn.

EXPANSION

Allen Hazen also proposed a formula for the expansion of filter sands

$$r = 30\, d^{1.5}\,(1 + .06\, x)\,\frac{t + 30}{80}$$

r = rise in inches per minute.
d = effective size.
x = percent expansion.
t = temperature in degrees F.

This formula may serve well under very limited conditions, but its application to the general problem of sand expansion is questionable. This is in agreement with the claims of its author.

Hulbert and Herring's formula:

$$r = [1.04 + .01\,(t - 32)]\,(s - .17)e + \frac{5.9}{1 - (s - .17)} + 0.24\, s(t - 32) - 7.4$$

s = 30 percent size.
e = percent expansion.
t = temperature in degrees F.
r = rise in inches per minute.

The work of Hulbert and Herring is related to the original work by Hazen in that the 30 percent size to describe expansion was arrived at in much the same way that the 10 percent size was for filtration. The equation is a refinement on the results of previous workers.

Fair and Hatch have been able to show that their equation for filtration may be applied equally well to expansion, since the two problems do not differ in their hydraulic aspects. This is accomplished by

solving for the porosity after substituting the weight in water of the sand for the loss of head.

$$\frac{f_e^3}{1-f_e} = \frac{k}{g}\frac{m}{R-r}v\left(\frac{s}{d}\right)^2$$

$$\frac{L_e}{L} = \frac{1-f}{w}\left[\text{Sum of } \frac{P}{1-f_e}\right]$$

f_e = expanded porosity ratio.
k = expansion constant = 4.
m = viscosity.
R = density of sand.
r = density of water.
v = velocity over gross area.
s = sand shape factor.
d = geometric mean of the rated sizes of adjacent sieves.
L_e = expanded depth.
L = original depth.
f = original porosity ratio.
w = total weight of sand analyzed.
P = weight of sand retained between sieves.

PRESENT STATUS OF SAND PARTICLE SIZE DETERMINATIONS

Considerable emphasis has been placed upon the determination of particle size. If we are to define sand by a hypothetical quantity, such as a percent size, which in some way does describe the hydraulic properties of that material, then it makes little difference what method is used to measure the sand so long as that method will give consistent results for any given sand. Filter sands are measured at the hand of a sieve analysis, fundamental to which is a calibration of the sieves. This is done by a measure of the sieve openings (Manufacturer's rating), by a measure of the particles just passing that sieve (Hazen's rating) or by microscopic measure of a representative number of particles retained on any sieve. Any one of these methods will give a fixed rating of a given sieve and if there is a reasonable distribution of sieves within the series, there should be a definite relationship between each one of the three ratings. Qualitatively it seems immaterial which one of the methods is adopted. The manufacturer's rating, however, is the most convenient measure and one which could easily become standardized. If we define sand in terms

of the surface area and volume of particles, it is necessary to combine a factor of shape with the particle diameter. Here again it makes no difference which one of the methods of measurement is employed. This reasoning applies mainly to the measurement of filter and ground water sands. There are industries of course where the linear dimensions of the particles are of primary importance.

RECOMMENDED RESEARCH

(Reproduced in Committee Report)

COAGULATION WITH IRON COMPOUNDS

By A. P. Black

(Professor of Chemistry, University of Florida, Gainesville, Fla.)

Ferrous sulfate in conjunction with lime was first used in this country as a coagulant in 1898 by Bull at Quincy, Ill. (6). Interestingly enough, he seems also to have been the first in this country to investigate the ferric salts, since he used ferric chloride experimentally at both Chicago and Toledo in 1910 (10). However, Duyk had used ferric chloride at Middlekerke, Belgium as early as 1902 and his process was reported upon by Whipple (16) at the 26th Meeting of this Association in 1906. During the past 30 years, the combination of ferrous sulfate and lime has been extensively used in this country, particularly in the middle west and mainly for the removal of turbidity. The treatment has not, as a rule, proved satisfactory for color removal, since the color is "fixed" or "set" at the high alkalinity necessary for the oxidation of the ferrous iron. Furthermore, incomplete oxidation may result in high values for residual iron in the treated water.

Recent years have witnessed a definite reawakening of interest in iron compounds as coagulants. Several reasons may be cited for this renewed interest. Miller (12) included ferric salts in his coagulation studies published between 1923–25. Mohlman and Palmer (13) employed them in their important investigations carried out in 1925 on the coagulation of activated sewage sludge. They found ferric chloride to be superior to all other coagulants tried for that purpose. The cost of ferric salts, formerly almost, if not entirely, prohibitive, has been reduced to a figure which allows them to compete with alum. Most important of all, however, is the fact that ferric compounds possess certain characteristics which render them definitely superior to alum when used in the treatment of certain types of waters. It is the purpose of this paper:

(1) To review very briefly the fundamental theory involved in the process of coagulation with iron compounds and with alum.

(2) To present results which are being obtained with ferric coagulants in the treatment of various types of waters.

(3) To summarize the advantages which may result and have resulted from the use of ferric coagulants.

THEORY OF THE COAGULATION PROCESS

Hyatt patented the use of alum as a coagulant back in the 80's in an attempt to duplicate by chemical means the "schmutzdecke" on the surface of the slow sand filters then in use, yet our knowledge of what really takes place during the coagulation process was to come many years later. Hale (11) in an important paper published in 1914 laid the foundation for much of the work which was to follow. Without giving at this point specific references to the now extensive literature, the facts which are necessary for a clear understanding of what takes place during coagulation will be briefly stated, and the action of iron and aluminum salts compared.

MECHANISM OF COLOR AND TURBIDITY REMOVAL

Both iron and aluminum flocs form first as colloidal microcrystals bearing a positive charge and are capable of neutralizing and precipitating the negatively charged color colloid. In addition, the gelatinous flocs possess high adsorptive power. In the acid range, the positively charged trivalent ferric and aluminum ions are likewise highly effective in precipitating the negatively charged color colloid (12). This action gives rise to "color flocs" which may have absorptive properties far superior to the true iron and alum flocs just mentioned (9, 13). In turbidity removal it is probable that the adsorptive capacity and specific gravity of the floc particles are the important factors, although colloidal precipitation undoubtedly plays a part.

IMPORTANCE OF HYDROGEN-ION CONCENTRATION

The pH at which the floc is formed exerts a decided effect upon the time required for its formation and the effectiveness of its action (2, 5). Furthermore, the pH value of the water governs the solubility of the floc itself (7). It is in this respect that ferric coagulants are superior to alum, since ferric floc is relatively insoluble over the very wide pH range 3–13, whereas alum floc is relatively insoluble in the much narrower pH range 5–9. It is evident, therefore, that the use of ferric compounds permits of much greater flexibility in the coagulation process and makes possible results which cannot be obtained with alum. This is probably the most important difference in the

action of these compounds. Recent work indicates that the sign of the colloidal floc changes from positive in the acid range to negative in the alkaline range (1). This may explain in part the difficulties often experienced in color removal in the alkaline range.

INDIVIDUALITY OF NATURAL WATERS

The ions derived from the mineral salts present in natural waters have been shown to exert a decided effect upon floc formation (2, 5). In the acid range the bivalent sulfate ion is most effective; in the alkaline range the bivalent calcium and magnesium ions are most effective (1, 5).

FERRIC COMPOUNDS AS COAGULANTS

Three ferric compounds are at present commercially available; chlorinated copperas, ferric sulfate, and ferric chloride. The first is a mixture of ferric sulfate and ferric chloride obtained by the oxidation of copperas with chlorine gas. In practice approximately 8 pounds of copperas may be oxidized by one pound of chlorine. The material is produced in the plant as required and fed as a solution. Ferric sulfate is available in several forms. An anhydrous product contains as high as 96 percent ferric sulfate and may be handled, stored in bulk, and fed by dry-feed machines. Ferric chloride is available either in solid form or as a concentrated solution containing 50 percent or more of the salt. Ferric sulfate does not dissolve readily in dilute solution and provision must be made to dissolve it under the proper conditions. Furthermore, solutions of the ferric salts are highly corrosive. Bean (3) has recently described a method used at Providence for handling ferric sulfate which has proved satisfactory. Rubber-lined tanks, pipes, valves and fittings are used.

Credit is due Enslow and Hedgepeth for the first successful application of a ferric coagulant to water treatment in this country (12). They used it in 1927 for the treatment of a soft, highly colored water at Elizabeth City, N. C. It is fitting, therefore, that this practical discussion of various ferric coagulants should begin with the results now being obtained by Luther at Elizabeth City.

Elizabeth City, N. C.

The raw water has a pH of approximately 5.5, with color ranging from 250 to 1000. Primary coagulation is carried out with chlo-

rinated copperas at a pH of about 4. It is interesting to note that the color of the raw water can not be used to determine the amount of coagulant required. A water of low color may at times require two to three times as much coagulant as is required at other times, although the pH may be identical in the two cases. Excessive dosage of coagulant results in an increase in residual color. The water then receives a secondary coagulation with sodium aluminate, raising the pH to approximately 4.8, at which point complete color removal is obtained. The water is settled and filtered at this pH value. Freedom from corrosion and "red water" is attributed to a protective coating of organic matter which seemingly has formed on mains and fixtures. Any attempt to raise the pH to 7 or above has resulted in a redissolving of the color and a precipitation of organic matter.

Dallas, Texas

Billings (4) has recently reported results obtained at Dallas, Texas, where the problem is that of turbidity removal. The water is moderately hard, and the turbidity varies from 50 to 5000 p.p.m. For years, ferrous sulfate and lime had been used. Substitution of chlorinated copperas for the ferrous sulfate has resulted in better and more effective coagulation, and a decided reduction in the cost of treatment. A secondary coagulation with alum is used immediately before filtration. This reduces the high pH resulting from the use of lime. The average saving over a period of several months has been 67.6 cents per million gallons or about $4000.00 per year.

Providence, R. I.

In 1932, Craig and Bean (8) reported results obtained at Providence, R. I. with all three ferric coagulants and concluded that there was less than 10 percent variation in results obtained when they were compared on a basis of equal iron content. More recently, however, ferric sulfate has been found by them to be superior to either chlorinated copperas or ferric chloride. The coagulating effect of the sulfate ion, previously referred to, may be an important factor. A concentrated solution of the coagulant is introduced into the raw water which is then aerated. Following aeration, lime is added to slight alkalinity. Lime dosage is followed by a thorough mixing and approximately two day's sedimentation before rapid sand filtration. This treatment results in the effective removal of both color

and manganese, and the production of a non-corrosive and stable effluent, exceedingly low in both iron and aluminum.

Pacific Coast area

Stevenson (15) reports the successful use of ferric chloride in several West Coast Cities. At Antioch, Cal., one-half grain of ferric chloride has replaced one grain of alum for the coagulation of a soft, highly turbid water. Filter runs have increased 200 percent and odor troubles have abated. At Beverly Hills, Cal., one-half grain of ferric chloride has replaced one grain of alum in a combined softening and filtration plant. Five grains of lime are used. Hydrogen sulfide is removed, and excellent results obtained. At Wilmington, Cal., ferric chloride has given excellent results in the treatment of a soft, colored, well water. San Diego and Lenox, Cal., and Prescott, Arizona, also report the successful use of this coagulant.

SUMMARY OF ADVANTAGES

The following advantages have been reported as resulting from the use of ferric salts as coagulants:

1. Coagulation is effective over a much wider pH range than with alum. Color flocs may be formed in the very acid range, where alum may not be employed. On the other hand, true hydrated ferric oxide flocs may be formed at pH 9–10 or even higher for the removal of turbidity and manganese.
2. The time required for floc formation, conditioning, and settling is in many cases considerably shorter than that required for alum.
3. Filter runs have been markedly increased in several cases.
4. Manganese is successfully removed at pH values above 9.
5. Effluents may be produced which are exceedingly low in both iron and aluminum.
6. Hydrogen sulfide is removed, and taste and odor improved.
7. Ferric floc does not seem to stick to sand grains to form mud balls, and is subject to less "breaking through" on the filters.

The author wishes to thank Messers E. L. Bean of Providence, R. I.; L. C. Billings of Dallas, Texas; Ralph A. Stevenson of Los Angeles, Cal.; and R. W. Luther of Elizabeth City, N. C. for their coöperation in furnishing much hitherto unpublished data; and Mr. L. H. Enslow for valuable suggestions, and the use of some material published in "Water Works and Sewerage."

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TASTE AND ODOR CONTROL

INTRODUCTORY STATEMENT

By John R. Baylis

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No development in water treatment has received greater approval by the public than the elimination of objectionable tastes and odors. It is gratifying to see so many water works officials making real efforts to give the consumers more palatable drinking water. The old type of water works superintendent who, a few years ago, thought the consumers should be satisfied with any kind of water delivered to them is gradually changing his views, or is being forced to take action to improve the palatability of the water for fear of public condemnation.

The time is rapidly approaching when the odor test will be regarded as one of the several indispensable tests on water. It will equal in importance the residual chlorine test, which probably is regarded as the most important test on water at the present time. Until recently, the odor test has not been very reliable, but improvement has been made in the procedure and it is possible to detect by test any odor which may be detected by the consumer who has a very keen sense of smell. Any water shown to be free from odor by the hot odor test, using the new procedure, will not have odor that can be detected by any one in any use of the water.

Treatment for taste and odor elimination at the present time is largely to level off the peaks. This is a great improvement over doing nothing, but still is not perfection. Sea level, or zero taste and odor must be reached, or so closely approached that there cannot be objections to the taste by any of the consumers. The water works official of today who boasts that he is spending 25 to 50 cents per million gallons for taste and odor elimination will soon be boasting that he is producing zero odor water, even though it costs 5 to 10 dollars per million gallons. Ten dollars per million gallons represents a cost of only 50 to 60 cents per year per person in the average city, and is a cost which will be readily approved by practically all of the consumers.

AT MINNEAPOLIS, MINNESOTA

By Arthur F. Mellen

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The problem of taste and odor control is threefold, involving removal to a satisfactory degree of:

1. Tastes and odors present in the raw water.
2. Tastes and odors produced during treatment.
3. Plankton forms which may cause tastes and odors in the distribution system.

There are two purification plants using water from the Mississippi River, one the Columbia Heights plant of 78 m.g.d. capacity and the other the Fridley plant of 80 m.g.d. capacity, both being located North of the city. Previous to 1930 we had a few complaints for short periods usually in the spring and fall. We were greatly puzzled to know why these complaints came principally from the farther half of the distribution system. It did not seem logical to believe that the residents of that section of the city were more discriminating than those living nearer the plants. It should be emphasized that there is no relationship between these difficulties and dead ends or poor circulation in the distribution system. From observations made later we now believe that the trouble was due to plankton passing the filters in such numbers that tastes and odors were released from the plankton when they disintegrated in the farther half of the distribution system.

In 1930, during a heavy onset of plankton in the raw water, we increased the alum treatment from approximately 2.50 to 6.00 grains per gallon, but did not find that an improved removal was effected. This spring, while on a 0.30 g.p.g. treatment, which was sufficient for an adequate color removal, there was a sudden increase in plankton in the raw water at a time when we were not pre-chlorinating. Wishing to try coagulation with alum again the treatment was increased to 2.00 g.p.g. at the Columbia Heights plant resulting in excellent plankton removal as shown by the counts in the finished water. Because of this experience and feeling that the 2.00 g.p.g. treatment was probably excessive, we then tried 1.50 g.p.g. at the Fridley plant, but found no improvement over the 0.30 g.p.g. treatment. While this was being tried out at the Fridley plant the treatment at the Columbia Heights plant was reduced from 2.00 to 1.75 g.p.g. which

resulted in an inferior effluent. To see if the improved conditions could be re-established we then increased the alum treatment at each plant to 2.00 g.p.g. and secured excellent plankton removal. Apparently there was a critical point in coagulation when plankton were present in great numbers, but this point was not found in the 1930 experiments.

Even if alum could be depended upon to make a satisfactory plankton removal under all conditions it would have the disadvantages of being more expensive than the pre-chlorination—carbon treatment and carbon would no doubt be needed with it if odors existed in the raw water before treatment.

Chloramines have been tried on the raw water but found unsatisfactory as to plankton removal. Compressed air introduced into the mixing chamber in large volumes has not caused an appreciable odor removal.

With increasing odors and plankton in the raw water we now use prechlorination in amounts, as a rule, from 15 to 20 pounds per million gallons. There is evidence to show that pre-chlorination is particularly effective with the filamentous plankton forms and the reaction probably aids the coagulant to enmesh the non-filamentous forms making a better removal of the latter than would otherwise be the case.

The use of powdered activated carbon applied with the coagulant before pre-chlorination gives very good results in taste and odor control, the quantity used varying from about 7 to 28 pounds per million gallons.

We have had a small experimental granular carbon unit in continuous service for over three and one half years. The results have been excellent under all conditions, some of which were very severe in 1931 and the carbon bed has not been changed during that time. A 500,000 gallon per day granular carbon unit was constructed and in service for over two years. Feeling that it might be necessary to give serious consideration to the construction of carbon units at both filtration plants we wished to secure information concerning the design of the underdrain system and of the collectors, the most advantageous depth of the carbon bed and rates of flow as well as the effectiveness and life of the carbon and the cost of its regeneration or replacement. However, in spite of lower elevations in the Mississippi River the raw water conditions have improved and because of the favorable results

obtained by the use of pre-chlorination and powdered activated carbon it seems improbable that it will be necessary to construct carbon units, so this experimental unit was recently taken out of service.

It is interesting to notice that our sand filters have a marked capacity for taste and odor removal. We have four ages of filters at the two plants; one set 21 years old, one set 15 years old, but used only about four months per year during the past seven years, one set 7 and one set 3 years old. Hot odor determinations on samples from each of these four sets showed in 1931, before proper control treatment had been worked out, a marked decreasing intensity of odor with the increasing age of the filters. Identification of the source of the samples was made at the time on unknowns from the four different sets mentioned by hot odor determinations. The difference is so marked that with pre-chlorination in each case the older filters at the Columbia Heights plant, where no carbon is used, will made as good a taste and odor removal as the newer filters at the Fridley plant where powdered carbon treatment is used with the alum before pre-chlorination. Whether the older filters are more effective because of the organic matter in the sand bed or whether the manganese compounds with which the sand is heavily coated may act as a oxidizing or catalytic agent is not known. This problem is being studied and if it is found possible to produce artificially, in the case of the newer filters, conditions similar to those effecting the improvement in the older filters, such a step would warrant serious consideration.

It is also of interest to notice that the taste and odor removal is in the same direction as and roughly proportional to the chlorine removal through the filters; that is, if the residual chlorine value is the same in the water applied to all the filters those making the greatest taste and odor removal will also make the greatest chlorine removal.

It is probable that filter effluents of all purification plants have a measurable amount of turbidity and under conditions such as those here described it may be due principally to plankton. We find that turbidities in filter effluents can be measured with a very high degree of accuracy with a Hellige turbidimeter.

More intensive study should be given to the problem of plankton in finished water. Standard Methods of Water Analysis does not mention this matter. It has been suggested that counts of from 300 to 500 per cc. might not be objectionable, but it would be better to describe any standard in terms of standard units and it is apparent

that the particular forms, because of varying capacities to produce tastes and odors, would affect the permissible concentration.

AT SAGINAW, MICHIGAN

By Alfred Eckert

(*Superintendent of Filtration, Saginaw Water Works, Saginaw, Mich.*)

The City of Saginaw has a modern water plant which was placed in operation during the late fall of 1929. The raw water supply is drawn from the Saginaw River, which has a drainage area of over 6,000 square miles above the city and a few hundred square miles below. On this drainage area above the City is located the Dow Chemical Company, five beet sugar plants and a rapidly growing oil field. The combined wastes of these industries together with municipal sewage, give us a raw water with a heterogeneous mixture of chemicals in solution which result in extremely objectionable periodic tastes and odors. Algae growths in the summer and fall further complicate the taste and odor condition.

Several smaller streams unite a few miles above the City to form the Saginaw River. It is not unusual for a reversal of flow in the river to be set up opposite our intake due to wind action and a distinct division of flow of the tributaries also frequently occurs. As a result of these phenomena, the character of the raw water is subject to rather sudden changes.

The water is softened to 100 p.p.m. with lime and soda ash followed by recarbonation, is chlorinated, and powdered activated carbon is applied just before it reaches the surface of the filters.

Several years ago, Mr. Charles P. Hoover reported upon taste and odor conditions of the Saginaw Water Supply. He made numerous tests on our water, using various methods for taste and odor removal, which had been successfully used at other plants throughout the country. To treat Saginaw River water successfully with chemicals was found to involve prohibitive costs and he consequently recommended the use of activated carbon.

Powdered activated carbon has been continuously used for over three years with very satisfactory results, except at several periods during the year when the combined effects of industrial pollution and low stream flow resulted in loadings on the plant which prevented successful treatment.

Through the coöperation of the Industrial Chemical Sales Company who provided the excess carbon required and also the services of a chemist from their organization to work with our plant chemist, a series of experiments were run over the period of a month during the past fall in an effort to eliminate odors in our water supply when they were at their worst. The following is quoted from a report by Mr. Henry Laughlin on these experiments:

"Since previous experience had shown that carbon worked most effectively when added to clarified water, we decided to follow along with this practice for the time being. Laboratory tests on raw water indicated that doubling the 9.4 p.p.m. dose of carbon then in effect might give desired taste and odor removal. Accordingly the dosage was stepped up to 20.4 p.p.m.

"The filter effluent seemed to show no improvement after 24 hours continuous use of this increased carbon dosage. We then had one filter washed and put back into service to see if above result may have been due to odor particles clinging to sand in filters, and then being slowly carried through by what would otherwise have been odor free water to clear well. After a few hours the effluent from filter which had just been washed showed an appreciable reduction in odor in comparison to one being run in parallel to it. This indicated one of two things: (1) The increase in carbon fed into the water was reducing odor in water, the odors had simply accumulated on sand in filters and washing removed this condition, (2) or the water being passed through the two parallel filters did not have the same amount of odor present.

"The odor in water from filter most recently washed gradually increased until it was as bad as that from filters in service before carbon dose was changed. A possible explanation for this was that the increased dosage of carbon, laden with odors, was being carried to filters, and the water passing through layer of carbon particles containing the odor was carrying odors from carbon into filter effluent. The residual chlorine dropped very low (0.02 p.p.m.) due to the carbon feed.

"For the above reasons we decided to change the point of carbon application from clarified water to mixing chamber, with a small amount of carbon still going to clarified water. This introduction of carbon earlier in the system would, we hoped, allow carbon to pick up all taste and odor particles possible and settle out with sludge, which is removed continuously. This would possibly prevent any

carbon carrying over on filters, and also prevent any possible chlorine adsorption. The carbon would be in water for about 5.5 hours before removal with sludge, so that ample time would be allowed for taste and odor adsorption. This neglects the influence of floc formation.

"The residual chlorine regained its original figure of 0.07 p.p.m. due to change in carbon application point. Odors in finished water were reduced but not sufficiently so.

"The carbon dose was increased to 25 p.p.m. with 2 p.p.m. going to clarified water. This treatment did not produce a noticeable change in odors. Therefore, the dose was changed to 42 p.p.m. at mixing chamber with 2 p.p.m. to clarified water. This application did not noticeably change odors present. The carbon dose was raised to 51 p.p.m. in mixing chamber and 8.5 p.p.m. to clarified water. This change in the amount of carbon added to clarified water was made to determine the effect of altering the concentrations at different points of application. The tastes and odors were improved. In order to determine whether or not the application of carbon to clarifier was doing any good we raised carbon dose at mixing chamber to 68 p.p.m. and kept 8.5 p.p.m. dose to clarified water. The resultant water had the same amount of taste and odor as the previous dose of 51 p.p.m. to mixing chamber and the 8.5 p.p.m. dose to the clarified water. This showed that the reasoning earlier in the experimental work must have been at fault and the clarifier was proper point for a more effective carbon treatment.

"Therefore the 68 p.p.m. were added to clarified water and 8.5 p.p.m. were added in the mixing chamber. This change made it necessary to chlorinate after filtration, because the large dose of 68 p.p.m. would remove all the chlorine added, before it had a chance to work on impurities in water. This treatment made the water free from taste and the cold odor negligible, with a small amount of odor when heated.

"Since the continued application of 76.5 p.p.m. of carbon was financially impossible in a plant pumping as much water as at Saginaw, even for a period of three months, our next consideration was to make the taste and odor control economical enough for use.

"The obviously necessary step was to cut down the carbon dosage, which was dropped to 34 p.p.m. to clarified water and 3.5 p.p.m. to mixing chamber. This resulted in an increase in odor present in the finished water.

"Some laboratory tests indicated that potassium permanganate

would effectively remove beet sugar waste odors from raw water when used in concentrations of one p.p.m. Enough $KMnO_4$ was purchased to conduct a plant scale test. We decided to use it in raw water, as this seemed to give best results in the laboratory. The carbon dosage was maintained at 37.5 p.p.m. as before and the 1 p.p.m. $KMnO_4$ was added to water before any other treatment. The permanganate had 5 minutes contact with water before it entered the mixing chamber. This treatment produced a medicinal taste in the water, with odor remaining the same as it was before the addition of permanganate.

"The permanganate feed was dropped to check medicinal taste formation and also find if odor situation would be affected by change. The medicinal taste disappeared and odors remained the same.

"It was thought possible that the excess lime-soda would possibly change the character of the pollution, in such a manner that permanganate, if added after coagulation, would not produce this disagreeable medicinal taste. This would also allow longer contact period. At the same time we decided to add chlorine before filtration. In order to do this we decided to use the ammonia-chlorine treatment, adding ammonia to the mixing chamber, and chlorine to coagulated water. A ratio of two parts of chlorine to one part of ammonia was used. $KMnO_4$ was added to coagulated water with dosage of 2 p.p.m. This increase over 1 p.p.m. used in raw water was made as laboratory tests indicated increased requirements at this point. Odor was still present after this treatment, but taste was not noticeable.

"The permanganate feed was stopped, and the odor did not change. The $KMnO_4$ did not seem to be producing any effect on odor removal.

"The residual chlorine jumped from about 0.08 p.p.m. to 0.2 p.p.m. due to ammonia carrying it through. The bacterial count was not at any point in the plant lowered from delayed action of chlorine in combination with ammonia as is sometimes the case.

"The bacterial count of the clarified water was around 10–12 per c.c. before chlorine is added and that of the finished water from 1 to 5. As a rule the finished water count is about 2 per c.c. It is seen from this that the high pH maintained through coagulators and clarifier destroyed most of bacteria present. The addition of chlorine to coagulated water did not lower clarified water bacterial count to any extent, and the finished water count was still as low as before.

"It was suggested that if the pH could be lowered, a better odor

adsorption might be effected. The CO_2 was changed from 33 to 85 p.p.m. in an effort to bring about the above condition. The pH was not lowered appreciably, only 0.4. This did not produce any change in odors present, but did increase the hardness considerably.

"The 34 p.p.m. of carbon going into the clarified water at this time produced a water which was not particularly bad for drinking, in fact that the odor was nearly negligible.

"By a negligible odor we mean one which would be detected by one who has a keen sense of smell, but not by the average consumer. The odor in water characterized as "nearly negligible" could probably be noticed by the average consumer if his attention would be called to it. However, we realize that the boundary set up between "negligible" and "nearly negligible" odors is subject to very great variations in different individuals.

"The carbon feed was dropped from 34 to 17 p.p.m. with application continued at end of the clarifier. The ammonia and chlorine remaining the same as before. The lowering of the amount of carbon fed into the water increased the odor present in finished water, although there was no taste noticeable.

"Potassium permanganate was again applied to the coagulated water, and again no improvement was noticed. The $KMnO_4$ feed was discontinued.

"Up to this time the samples of finished water had been taken directly from a single filter effluent. We decided that a more representative sample would be obtained from some point on the line from the filters to the clear well. Accordingly samples were taken from an open chamber in the main gate house. This chamber serves simply as a sort of manhole to do repair work and is a break in the main from the filters to the clear well.

"The carbon dosage was raised to 34 p.p.m. and this change did not produce any better results than 17 p.p.m. In trying to find a reason for this, samples taken from the main carrying water from the filters to the clear well were compared with those from single filter effluents and it was found that the samples from the main contained much more odor than the others.

"A possible explanation for this increased odor in one sampling point is that the water is delayed somewhat in passing through the chamber because the current is at bottom and there is a tendency for the water on the top to remain stagnant for a time. Therefore, we compared effluents from each of the filters in service at the time and

could not distinguish any difference between any two of them. This indicated that a filter effluent sample was representative of the treatment results. The odor in water treated with 34 p.p.m. carbon, from filter effluent was not in high enough concentrations to warrant consumers' complaints.

"In regard to our report of results from each change in treatment, we formulated each result by averaging the reaction of several observers. In some cases one observer would give an opinion of "no odor," while another would state "odor present." Quite often we found that the odor in a sample was so slight that when an observer who used tobacco handled the flask previously the tobacco odor entirely masked any other that may have been present.

"The carbon dosage was dropped again to 17 p.p.m. with an increase in odor.

"At this point in the work, it seemed fairly well proven that, for water as was being processed, the 17 p.p.m. feed was inadequate, and that a 34 p.p.m. dosage was necessary when application was made to clarified water.

"We decided to try 17 p.p.m. carbon on filters direct. At this time the water in the plant from the clarifier on, had already received a 17 p.p.m. dosage, so that the finished water was the result of 17 p.p.m. in the clarified water and 17 p.p.m. on the filters.

"This combination gave the best results so far obtained. The odor was negligible. Whether this was due to carbon being applied to filters, the 34 p.p.m. dose of carbon, or a change in the pollution was impossible to say. However, the carbon feed to clarifier was shut off and the odors remained negligible. Therefore, we recommended that the following procedure be used in treatment.

"Ammonia in the form of $(NH_4)_2SO_4$ to be applied to the mixing chamber in a ratio of 1 to 2 to chlorine used, along with the lime and soda necessary for softening; chlorine to be applied to the clarified water before entering sedimentation basin; 17 p.p.m. carbon to be applied to water as it goes on the filters.

"The cold odor of the water so treated was so slight that it was nearly what would be called a threshold point in the Threshold Odor determination procedure."

The recommended treatment including the ammonium sulphate application was used for several weeks, but the improvement in the quality of the finished water was not of sufficient consequence to warrant the expense of its continued use with 17 p.p.m. of carbon.

Early in January, after the intensive fall campaign of the sugar factories was completed, the odors in our finished water disappeared almost as suddenly as they appeared early in the fall. One-half grain per gallon of carbon met our requirements.

At the present time, however, we are again beginning to feel the effects of accumulated industrial wastes upon the diminished flow in the tributaries of the Saginaw River, resulting from a lack of normal precipitation. The raw river water has an unmistakable odor which is noticeable in driving an automobile along the highway paralleling the Saginaw River. Although both hot and cold odor tests on the finished water leaving the plant are still negative, the tap water throughout the city now has a disagreeable hot odor.

The chemist at the water plant according to his daily records may show and honestly believe that the water leaving his plant is entirely free of taste and odor, but the consumer is the final judge in the matter and he does not hesitate to express his opinion if either the cold or hot water in his home has an objectionable taste or odor. Taste and odor control implies elimination of these objectionable features in a public water supply to such a degree that the consumer does not find cause for complaint.

Due to excessive industrial pollution it has not been found economically possible to satisfy the majority of consumers in Saginaw with our present public water supply. Confidence gained over a period of months is shattered when tastes and odors typical to the industries located above the City, reappear. We have found it more expressive to refer to these odors as "Dow" odors or "Sugar Beet" odors rather than the conventional descriptions as listed in Standard Methods.

Obviously, the best and most economical solution for a problem such as ours, is better control or proper treatment of industrial wastes at their source. A very pertinent editorial discussing industrial pollution appeared in the April issue of "Water Works and Sewerage." This editorial was entitled "Industry Should Pay" and it very clearly expresses the thought in the title that industry should pay their share of the bill for water purification while taking steps to curtail pollution and relieve the burden on the municipal plants incidental to their operation.

AT HACKENSACK WATER COMPANY, NEW JERSEY

By George R. Spalding

(*Sanitary Engineer, Hackensack Water Company, New Milford, N. J.*)

Odors and tastes in water supplies can be grouped generally into two classes (1) those that are introduced into the water during the course of its collection and impounding and (2) those that develop in the supply during the purification process or in the distribution system. In the first class there are odors and tastes due to natural causes such as decaying organic matter, in the manifold forms in which this occurs, and those odors and tastes that enter the supply through pollution. In the second class we find odor troubles arising from decomposing sludge in settling and coagulation basins and from stagnation in dead ends or other parts of distributing systems where circulation is poor and excessive oxygen depletion takes place. Recent work seems to indicate that electrolysis from stray currents may constitute another source of odors and tastes developing in distributing mains, service pipes and meters.

In any discussion of odor troubles it is well to point out that such difficulties are likely to be more pronounced in hot water systems employing storage tanks than in the cold water directly from the mains. This is particularly true where the odor producing substance is one of the volatile hydrocarbons of the benzene ring series. Furthermore, there must be a high degree of removal of such substances from water as small amounts, hardly detectable in the cold supply, become concentrated in the upper portions of hot water boilers. As the hot water is drawn off intermittently the first portions contain a high concentration of the contaminating substance.

The diversity in character and treatment of water supplies throughout the country is so great that odor and taste control becomes, in considerable degree, a matter for local solution. In that large group of water systems comprising the surface supplies, with treatment plants, there are common problems however which are being successfully overcome by one or more of the several agents now available for odor elimination. Introduction of the latest of these substances "activated carbon" several years ago focussed attention upon the whole subject of odor control in water supplies as a matter not to be side-stepped but to be attacked vigorously. Successful application of this material in preventing odors from decomposing sludge in coagulating basins has made it possible to eliminate one of the most

troublesome sources of odor production in purification plants. Long before it becomes economically feasible to remove the sludge from such sedimenting tanks the natural processes of decomposition will have set in, accompanied by odor production and gassing. Inasmuch as 80 percent of the purification in rapid sand plants takes place in the coagulation process it is apparent that the necessity to maintain coagulation basins free from the conditions described is paramount.

Throughout the whole course of travel of surface water from its collection and storage in impounding reservoirs to its ultimate de-

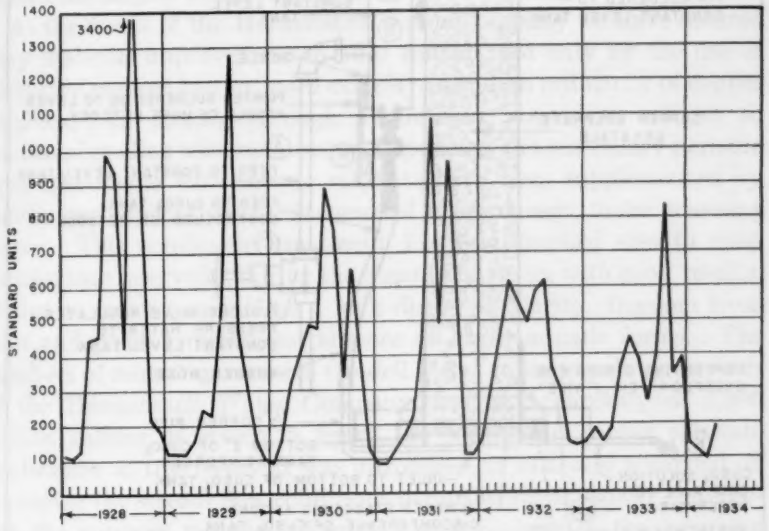

FIG. 1. MONTHLY AVERAGES OF DAILY MICROSCOPIC COUNTS IN RAW WATER. ORADELL LAKE, HACKENSACK WATER COMPANY

livery through distributing mains and service pipes we find a great variety of plant and animal matter going through the life cycle. This growth of organisms of one kind or another constitutes an important source of odor and taste troubles in many water supplies. The literature upon this subject is abundant and many commentators have called attention to the problems that arise from excessive development of these living forms. Such difficulties range all the way from odor and taste production in storage reservoirs, due to microscopic organisms, to the development of higher forms such as bryozoa, nematodes, caddisworms and shrimps. The development of small and large aquatic insects, which may become very annoying in water

systems is brought about by allowing deposits of decaying vegetable matter and mud to accumulate thereby harboring the development of

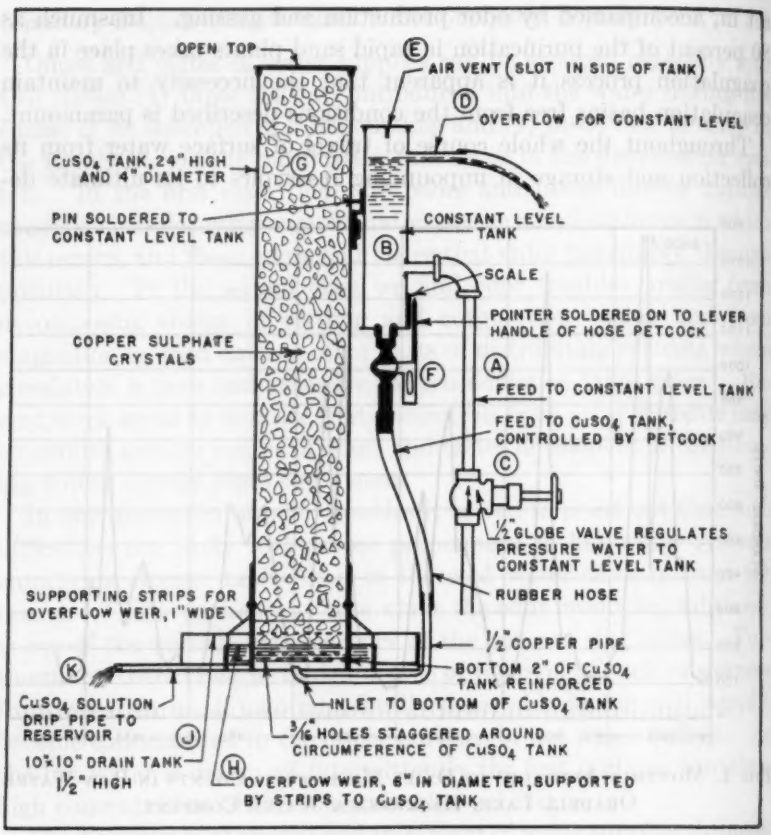
OPEN TOP
E
AIR VENT (SLOT IN SIDE OF TANK)
D
OVERFLOW FOR CONSTANT LEVEL
CuSO4 TANK, 24" HIGH AND 4" DIAMETER
G
PIN SOLDERED TO CONSTANT LEVEL TANK
CONSTANT LEVEL TANK
B
SCALE
POINTER SOLDERED ON TO LEVER HANDLE OF HOSE PETCOCK
COPPER SULPHATE CRYSTALS
F
A
FEED TO CONSTANT LEVEL TANK
FEED TO CuSO4 TANK, CONTROLLED BY PETCOCK
C
½" GLOBE VALVE REGULATES PRESSURE WATER TO CONSTANT LEVEL TANK
RUBBER HOSE
SUPPORTING STRIPS FOR OVERFLOW WEIR, 1" WIDE
½" COPPER PIPE
K
BOTTOM 2" OF CuSO4 TANK REINFORCED
INLET TO BOTTOM OF CuSO4 TANK
CuSO4 SOLUTION DRIP PIPE TO RESERVOIR
3/16" HOLES STAGGERED AROUND CIRCUMFERENCE OF CuSO4 TANK
J
10"x10" DRAIN TANK 1½" HIGH
H
OVERFLOW WEIR, 6" IN DIAMETER, SUPPORTED BY STRIPS TO CuSO4 TANK

FIG. 2. CONTINUOUS COPPER SULPHATE APPLICATION APPARATUS AS USED BY THE HACKENSACK WATER COMPANY

Pressure water (*A*) to constant level tank (*B*), regulated by globe valve (*C*). Overflow (*D*) with air vent (*E*) maintains constant head on tank (*B*). Rate of flow from tank (*B*) controlled by lever handle of hose petcock (*F*) which has a pointer soldered on lever handle, and reads on a scale attached to tank (*B*). Feed from tank (*B*) enters bottom of $CuSO_4$ tank (*G*) (which has a number of $\frac{3}{16}$-inch holes around its circumference) and then to a 6-inch in diameter overflow weir (*H*) 1 inch high, around base of tank (*G*). Feed from tank (*B*) maintains 1 inch depth in $CuSO_4$ tank (*G*), overflow of $CuSO_4$ solution spills over overflow (*H*) and into drain tank (*J*) and through overflow or drip pipe (*K*) to reservoir.

algae and protozoa and setting up the necessary food supply for the entire group. Such structures as filter beds, concrete clear-water wells, elevated tanks, pump wells and conduits should be cleaned frequently to prevent accumulation of organic matter and development of such things as bryozoa and other types on the bottom and sidewalls.

This process of controlling the amount of living and decomposable organic matter in the various units of a system requires the use of one or more of the chemical agents now available. Local conditions determine largely which ones to use.

At the works of the Hackensack Water Company we have secured very material improvement in odor control, not only by the use of activated carbon, but by more extensive use than ordinarily of copper sulphate. In flowing through impounding reservoirs, subject to continual seeding with microscopic organisms, the customary periodic boat treatments with copper sulphate have been supplemented by continuous application of this chemical in low dosage, to the incoming water. This continuous treatment has been applied also to open distributing reservoirs, during the Summer months, with good results. Water so treated maintains a high degree of clarity, freedom from odor and green growths and absence of larger aquatic forms. The numbers of microörganisms in Oradell Lake, an impounding reservoir of the Hackensack Water Company, having a capacity of 3,000 million gallons, is shown in figure 1. Continuous copper sulphate application to this reservoir was introduced in 1929 and is carried on whenever the stream flow conditions permit which is usually throughout the summer months. Removal of organisms in the incoming water by continuous copper sulphate application has assisted materially in keeping the seasonal growths of such organisms as anabaena, asterionella, synedra, melosira and synura below the point at which they become troublesome. The actual results in practice are more pronounced than figure 1 would indicate as the limitation of plankton growth not only results in greater freedom from odors and tastes but maintains the water in a condition much more favorable to subsequent treatment in the Rapid Sand purification process. In this respect the expense of such copper sulphate treatment is largely offset by savings effected in chemicals for coagulation and sterilization. Special apparatus for the continuous application of copper sulphate has been devised, one type of which is shown in figure 2.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the journal.

Water Works Reconstruction Financed from Earnings. H. F. WIEDEMAN. Public Works, 64: 9, 11–12, 1933. Reconstruction includes addition of mechanical mixing basins, chemical house, and laboratory. Mechanical details of mixers are given. Hydrated lime, before being added to clear well, is passed through a "settling cone" to remove inert matter.—*G. L. Kelso.*

Iron Removal Plant Paid for from Earnings. ROY E. WELLS. Public Works, 64: 9, 18–20, 1933. Water from well supplying 500 gallons per minute through deep-well pump direct into distribution system caused trouble by its high content of iron, hydrogen sulfide, and carbon dioxide. Treatment plant of 5 units was constructed. Aërator is of coke tray type, with total tray area of 120 square feet and total coke volume of 80 cubic feet. Water is delivered at 500 gallons per minute by centrifugal pumps to three pressure filters, 96 inches in diameter and provided with usual control valves. Solution feed equipment for soda ash and apparatus for determining hydrogen sulfide, carbon dioxide, and pH complete the installation. Aërator removes 65 to 75 per cent of carbon dioxide, remainder being neutralized with soda ash. pH of plant effluent is 7.8 to 8.0.—*G. L. Kelso.*

Simple Chlorination Equipment for Small Water Supplies. F. E. DANIELS. Public Works, 64: 10, 18 and 41, 1933. Detailed and elementary explanation of design, construction, and operation of simple chlorination and dechlorination equipment for small water supplies. Four sketches and method for calculating chlorine dosages are included.—*G. L. Kelso.*

The Bacterial Efficiency of Certain Intermediate Stages of Water Treatment. H. W. STREETER. Public Works, 64: 12, 17–20, 1933. [Cf. THIS JOURNAL, 25: 1802, 1933.] Data gathered from experimental plant studies and municipal plant operating records indicate that, compatibly with production of final chlorinated effluent with *B. coli* index not exceeding 1 per 100 ml., following are the permissible limits to *B. coli* population per 100 ml. at the indicated stages:—raw water, 6,000; applied water, 1,700; filtered water, 30. Results have been studied mathematically and equations derived to show: (1) relation of bacterial content of raw water to that of coagulated and settled water, as influenced by time of sedimentation; (2) effect of bacterial content of raw

water on efficiency of bacterial removal by coagulation and sedimentation, and effect of bacterial content of applied water on bacterial efficiency of rapid sand filtration; (3) maximum permissible concentration of *B. coli* at each stage, compatible with *B. coli* index not to exceed 1 per 100 ml. in final chlorinated effluent. Constants are given for different types of treatment.—*G. L. Kelso.*

The Disinfection of Drinking Water with Hydrosept-Heyden. HODER F. Med. Klinik, 1930, **26**: 959; Chem. Zbl., 1930, 2, 1111. Hydrosept tablets contain in one tablet sufficient chlorine to disinfect 1 litre of water. Process is accelerated by simultaneous addition of citric, tartaric, or acetic acid. The effect is due to nascent chlorine. Time required for action is 4 to 5 minutes from addition of tablet and acid. Taste of water is unaltered.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Chlorinating Apparatus (for Water). BLACKMOND, W. C. U. S. P., 1,752,723; Chem. and Indust., 1930, 49, Brit. Chem. Abst. B., 968. Apparatus described is easily operated and unlikely to develop leaks. Definite volume of chlorine gas is released periodically by means of pulsating device, period necessary to complete cycle of operations being under easy control.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Apparatus for the Purification of Water by Electro-osmosis. BECKER, J. Chem. Apparatur, 1930, **17**: 85; Chim. et Indust., 1930, 24, 323. Apparatus, consists of ten 3-cell systems in series. Concentration of secondary compounds during electrolysis in cathodic and anodic compartments is avoided by rinsing first cells with raw water and last two with water either distilled, or purified by electro-osmosis. Current consumed varies from 1.5 to 5 k.w. per 100 litres, according to mineral content.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Electro-osmotic Purification of Liquids. Siemens Elektro-Osmose G.m.b.H. G.P., 498,048; Chem. Ztg., 1930, **54**: 161. In electro-osmotic purification of liquids in space separated from electrodes by diaphragms, part of liquid to be purified is used for washing out electrode chambers.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Sterilization of Water by Solar Heat. L'Administration locale, 1930, No. 54, 1059. Description of still constructed by GINESTOUS for above purpose. Still, which consists of feed tank, insulated chamber, and collecting tank, can produce on average 3 litres per square meter per day of water suitable for all industrial uses. Method can also be used for producing fresh water from sea water and for extraction of water from soil, sand, or vegetables.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

De-aërating Water. BOBY, W., and BOBY, W., and Co. B.P., 332,678; Ill. Off. J. Patents, 1930, No. 2174, 3730. Brief description and diagram are given. —*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Water Purification (in the Paper-Mill). BERRIMAN, J. W. Proc. Tech. Sect. Papermakers' Assoc., 1930, **10**: 360; Chem. and Indust., 1930, **49**: B. 796. Filtration by gravity and pressure filters is discussed and description of plant given. Results of experiments on treatment with aluminum sulfate are included. Optimum condition for formation of filterable flocs is found to vary between pH 6.3 and 7.1, according to turbidity of water.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Sterilization of Drinking Water by Iodine. Le Génie Civil, 1930, **96**: 634. Sterilization by javellisation and verdunisation is considered with special reference to harmful effect of excess chlorine and necessity for determining exact amount of chlorine required. Work of V. CONTRERAS on use of iodine for sterilization is referred to. Iodine dissolves in water in proportion of from 1:6,000 to 1:10,000, producing brown coloration. Dilute alcoholic solution containing 1 part of iodine per 100 parts of ethyl alcohol at 40°C. can be used, but imparts iodoform odor to water. In general, 1 part of iodine is sufficient to sterilize 100 million parts of water. Concentrations used are of same order of magnitude as with chlorine, but excess of iodine has no harmful effect and is often beneficial in cases of goitre, etc. Georges-Vaillard tablets for sterilization by iodine, used during war time, and method recommended by TANON are described. Iodine can be used successfully for sterilizing very polluted waters and sewage effluents. For treatment of city supplies, iodine must be controlled in same way as chlorine, but control and apparatus are simpler.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Oligodynamic Action of Metals and Its Application in Medical Preparations. I. KUWADA, S., and SUZUKI, T. J. Pharm. Soc. Japan, 1930, **50**: 71; Chem. Zbl., 1930, 2, 2405. Water to which oligodynamic action has been imparted by copper or silver weakens or destroys *B. coli* and paramecia. Copper has more effect than silver. Variations of pH between 3 and 8 by addition of hydrochloric acid, or soda, do not affect oligodynamic action.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Chlorine-Silver Treatment of Swimming Pool Water in Combination with Chlorine-Copper Treatment. OLSZEWSKI, W. Gesund. Ing., 1930, **53**: 728. Disinfection of by silver requires time for secondary reaction, period varying with time of actual contact, with amount of silver taken up, and with turbidity. Process is too uncertain for drinking water. For pool water, continuous addition of silver ions is necessary. By combining with chlorination it is possible to reduce chlorine dose until no residual shows in pool effluent, provided

sufficient silver is present. Silver may be added directly as silver salt solution, or by passing direct current through silver electrodes in water, or by passing chlorine water, or sodium hypochlorite solution, over silver wool. In latter case, copper, being more soluble, can be used to supplement silver. Turbidity diminishes the effect, so that coagulation and filtration are advisable. Effect on algae growth is discussed.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Removal of Silicic Acid from Water. I. G. Farbenindustrie A.-G. F.P., 692,364; Chem. Zbl., 1931, 1, 663. Silicic acid is removed from water or other liquids by the addition of insoluble metal hydroxides, such as ferric hydroxide, ferrous hydroxide, zinc hydroxide, etc. For example, if 3 cubic meters of water containing 14 mg. silica per litre are stirred with 1.3 kg. of ferrous hydroxide, silica content is reduced to 0.2 mg. per litre.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Concerning the Filtration of Water through Brown Coal Ash, in Particular Through Ash of the Coke from Brown Coal. FRIEDBERGER, E., and SEIDENBERG, S. Arch. Hyg., 1930, 104: 255; Chem. Zbl., 1931, 1, 128. Advantages include almost complete bacterial removal, removal of coloring matter and iron, and also of manganese, lead, copper, arsenic, etc.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Sterilizing Water by the Katadyn Method of Krause. The Lancet, Aug. 2, 1930; Brit. Waterworks Assoc. Off. Circ., 1930, 12, 724. Oligodynamic effect of silver and copper vessels on micro-organisms in water, discovered by NÄGELI, was further studied by KRAUSE and others and Katadyn method of sterilizing water by finely divided silver distributed over carriers of different kinds has been critically tested. It is also claimed that filtrate retains germicidal powers. From commercial point of view, expense of materials and vessels requires scrutiny; but *prima facie* case for consideration of process by physicist, biologist, and public health expert has been made out.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Regulation of the Addition of Soda in the Purification of Water by Hot Soda Solution. KUNER, R. G. P., 510,178; Chem. Zbl., 1930, 2, 3830. Sodium carbonate solution maintained in equilibrium with solid sodium carbonate at temperatures from 40° to 104°C. may be used for purification of water.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Corrosion Problems in Central Heating and Hot Water Plants. Kröhnke. Ber. XIII Kongr. Heizung u. Lüftung, Berlin, 1930, 60; Chem. Zbl., 1931, 1, 847. After general discussion of theories of corrosion, author describes differ-

ent forms of rusting, i.e., uniform attack, pitting, and "sponginess" of cast iron, and their causes, and gives examples from practical experience. Finally, he deals with processes for corrosion prevention.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Purification of Boiler Feed Water. FILTRATORS LTD. Hungarian P., 98,339; Chem. Zbl., 1930, 2, 3831. Boiler sludge is forced under pressure into tank from which steam is led through reducing valve into feed water storage tank. After deposition of sludge, hot water from the sludge tank is also led into feed water tank. Greater thermal efficiency may be effected by leading hot water containing sludge through system of pipes in heat exchanger. The movement of liquid is controlled by pressure, about 8 pounds per square inch, in sludge tank.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

A City Drinking Water Supply with a High Salt Content. LÜNING, O. Z. Unters. Lebensmittel, 1930, 60: 331; Chem. Zbl., 1931, 1, 501. Well at Eschershausen, near Holzminden on Weser, rising from boundary of middle and upper red sandstone, yields distinctly saline water, containing 808 mg. per litre of chlorine, 103 of sulphur trioxide, 122 of calcium oxide, 59.7 of magnesium oxide, and traces of iron; but no ammonia or bacteria. Analyses made in 1897 show water to have had approximately same composition.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Sterilization of Liquids by Means of Metal Salts. KRAUSE, G. A. F. P., 690,713; Chem. Zbl., 1931, 1, 332. Liquids, in particular water, may be sterilized by means of extremely dilute solutions of salts of metals such as silver, mercury and copper in oligodynamic concentrations. Diagram is included.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Sterilization of Liquids. KRAUSE, G. A. Belg. P., 352,228; Chem. Zbl., 1931, 1, 817. The liquid flows, in as fine distribution as possible, amongst pieces of metal, e.g., copper, silver, or their alloys.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Purifying Water. ADLER, R. B.P., 340,202; Ill. Off. J. Patents, 1931, Group I, 4. Carbon used for dechlorinating water may be revivified and freed from compounds known as "Mellogens" by treatment with alkaline solvent and strongly active oxidizing agent. Alkaline solvent may be aqueous solution of hydroxide, carbonate, or phosphate, of alkali metal, or of ammonium, and oxidizing agent, aqueous solution of chlorine, hypochlorous acid, or hypochlorite. Treatment may be aided by heat. Alkali retained by carbon may be removed by subsequent treatment with soluble salts of alkaline earths, or of magnesium, such as chlorides, hypochlorites, sulphates, or nitrates.—*M. H.*

Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).

Softening of Water. LESCHIK, G. Belg. P., 352,415 and 352,416; Chem. Zbl., 1931, 1, 663. To water are added sodium carbonate and sodium borate and soluble aluminum salt, e.g., aluminum sulphate.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Eijkman's Test on Water-Supplies in the Madras Presidency. W. J. WEBSTER and T. N. S. RAGHAVACHARI. Ind. Jour. Med. Res. **21**: 3, 525, January, 1934. Tests were made on a number of samples of Madras waters running one set by the Eijkman-test and the other by the usual routine methods. The tests were made on well, river, lake and infiltration gallery waters. The Eijkman test has been found unreliable for Madras waters. For example, a water from a source exposed to pollution and showing true coli in 0.1 cc. may give a negative Eijkman test with amount up to 50 cc. There is frequent failure to recover true coli after 24 hours culture in Eijkman's medium at 46°C., while aerogenes sometimes survive under these conditions.—*A. W. Blohm.*

Comparison of MacConkey's Bile-Salt Broth and Dominick-Lauter Broth in Routine Water Analysis. T. N. S. RAGHAVACHARI and P. V. SITARAMA IYER. Ind. Jour. Med. Res. **21**: 4, April, 1934. Parallel tests on seventy-two samples of water, from different sources, were carried out using MacConkey's bile-salt lactose broth and Dominick-Lauter methylene blue brom-cresol-purple broth respectively as the enrichment and selective media. The test indicated that the MacConkey broth is more sensitive and more reliable. "Both as a selective medium for the presumptive positive test for coli, and as an enrichment medium to be followed up by subculture for the study of discrete colonies, and classification into coli, aerogenes and intermediates, MacConkey's broth (1.5 percent bile) retains its position as the most satisfactory medium in water bacteriology." "We have used this medium (MacConkey's) in this laboratory with uniformly satisfactory results for nearly a quarter of a century and false presumptive positives have never troubled us."—*A. W. Blohm.*

Selection of Deep Well Pumping Equipment. R. E. SWANSON. Presented at National Association of Well Drillers Convention, LaFayette, Indiana. There are innumerable conditions which must be taken into consideration when buying pumping equipment; size of well, pumping level, quantity of water desired, quality of water and operating conditions. Unless other conditions prohibit, the cost of pumping over a period of years should be the prime consideration. Single and double acting and turbine pumps are discussed. Instances are cited of the misapplication of turbine pumps where a plunger pump of greater efficiency would soon make up for the difference in first cost by its saving in power—*A. W. Blohm.*

An Explosive Prevalence of Typhoid Fever at Nagasaki City and Its Cause. YASUZO IIMURA. The Journal of the Public Health Association of Japan, **7**:

12, 1–3, December, 1931. From the middle of May, 1931, to June 15, 1931, one thousand ninety-two cases of typhoid fever were reported, followed in a few days by a second epidemic of 434 cases. For over a year it had been noted that heavy rains were followed by a great increase in bacteria counts at one of the four reservoirs and chlorination had been advocated but rejected by the city authorities. There had been a rain of unusual severity two weeks previous to the epidemic and as the reservoir under suspicion served mainly the area of the epidemic it was concluded that pollution of the reservoir was responsible for the outbreak. The occurrence points distinctly to the necessity of a more careful watch of the watershed supplying water for the larger cities of Japan.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

An Investigation of the Sterilization of Drinking Water by Means of Hydrosept Tablets and "Roh-Chloramine, Heyden." C. P. Mom. Mededeelingen Van Den Dienst Der Volksgezondheid in Nederlandsch-Indie, 20: 1931, Part 1, Foreign Edition. "Roh-chloramine-Heyden" consists of para toluol. sulphon-chloramine-sodium. Like all chloramines it has a powerful disinfecting action. Comparative investigations on the sterilization of drinking water with the chloramine, chlorine and calcium hypochlorite showed that 50 p.p.m. raw chloramine was sufficient to sterilize and prevent aftergrowths for 6 days. With this dose no chlorine taste was noticed. Similar results could be obtained with 0.75 p.p.m. of hypochlorite or 0.5 p.p.m. active chlorine. The cost of disinfection with raw chloramine would be 5 cents per cubic meter as against 0.06 cent with hypochlorite. A dose of 80 p.p.m. of raw chloramine was not sufficient to sterilize or prevent aftergrowth in purified river water (which contains the normal chlorine fixing impurities). With this dose the taste limit was reached. It is concluded that, "only in a few special cases this preparation has any value for the practical disinfection of drinking water, either used alone or in combination with chlorine or calcium hypochlorite. For use in municipal water works it is entirely unsuitable."—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Report of Division of Public Health Engineering and Sanitation. State Board of Health of Missouri. The typhoid death rate for the state as a whole increased from 5.00 per 100,000 in 1929 to 7.26 in 1930. This increase was probably due to the drought since in 67 non-drought counties the rate decreased from 3.6 per 100,000 in 1929 to 1930, whereas in the 47 southern counties constituting the drought area, the typhoid death rate increased from 8.7 in 1929 to 18.6 in 1930, an increase of 113.8 percent. There are 196 public water supplies serving 215 cities. Public water supplies are available to 56.5 percent of the state's population. Each municipal water supply was surveyed one or more times during the year, and 300 inspections are made. A special effort was made to eliminate cross connections with unsafe supplies and 19 defects of this sort were corrected. A signed statement stating whether or not cross connection existed with his system was obtained from each water works superintendent. Five new bacteriological laboratories were added at surface water plants, making a total of 16. A total of 10,409 bacteriological samples from public water supplies were analyzed. The Missouri State Highway Department

erects a special sign at the city limits of those cities having water supplies approved by the State Board of Health.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Report of Bureau of Sanitary Engineering, Wisconsin State Board of Health, for 1931. Investigations increased from 768 in 1930 to 1017 in 1931. Under water and sewerage are listed the changes in water supplies and sewerage systems and disposal plants from the list published in 1930 report. The typhoid death rate for 1931 is expected to be 0.7 per 100,000 as compared with 0.9 in 1930 and 1.4 in 1929. Seventeen major stream surveys were made during the year.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Planning the Outdoor Swimming Pool. LINDON J. MURPHY. Iowa State College of Agriculture & Mechanic Arts Official Publication, **29**: 45, April 8, 1931. To provide for the healthful recreation enjoyed in the old swimming hole of the past, municipalities are now providing modern hygienic pools, and in so doing assume definite responsibilities for safety and sanitation. From the sanitary standpoint the pool should have the following features: Adequate safe water should be supplied either by the fill and draw or continuous circulation process. Preferably the original supply should be from a municipal water system,—and if recirculated should be purified by filtration, sterilization, and algae removal with copper sulphate. Accessories to the purification such as vacuum cleaner including hair catcher, water heater if necessary,—etc., are advisable. A scum gutter to receive sputum and carry it away with a splashing overflow of water from the pool is important. The bath house should be arranged for cleanliness and convenience, with adequate dressing rooms, showers, and equipment room. Adequate regulations for the conduct of bathers should be exhibited and enforced.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Swimming Pool Permits. WILLIAM H. CARY. Detroit Department Health Swimming Pool Review, November, 1931. On August 13, 1931, the Michigan State Department of Health adopted regulations for control of swimming pools. After January 1, 1932, all persons operating a swimming pool must obtain a permit from the State Health Department. Unconditional permits will be issued only to pools meeting the minimum standards of construction and operation specified by the department. Conditional permits may be granted to pools not meeting minimum requirements with the corrections needed stated on the face of the permit. Plans for new pools or for alterations on old pools must be submitted to the department for approval. Under the new regulations the State Department may delegate its authority to local health officers who have facilities to handle pool supervision.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Albuquerque Builds Large Swimming Pool. J. D. HOLMES. Western Construction News, **6**: 20, 557, October 25, 1931. This is an earth swimming pool 4,000 feet long by 350 feet wide with a maximum depth of 15 feet. There is a beach 30 feet wide extending around the entire pool. Water is obtained

from a drainage ditch and is chlorinated.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Report of Mass Illness from Ingested Water on U. S. S. Vestal. C. W. BRUNSON. U. S. Naval Medical Bulletin, **30**: 1, 139, January, 1932. An explosive epidemic of gastro-enteric disturbance involving 105 members of the crew, from several messes, is described. A careful bacteriological, clinical and epidemiological study was made. The conclusion was reached that it was not an outbreak of food poisoning but an enteritis probably caused by some chemical content of the drinking water. Water, from a scuttle butt that had been filled from a reserve feed bottom, containing water from one or more of the engine boilers, had been used seven hours prior to the outbreak. The use of this water was necessitated by a breakdown of the evaporating plant. Bacteriologically this water was sterile. Chemical examinations were not made.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Village Control of Water Purity. L. F. WARRICK. The Municipality, **27**: 2, 19, February, 1932. Water carried disease epidemics have been steadily reduced in Wisconsin due to public appreciation of the need for safeguarding water supply. The typhoid fever rate for 1930 was 0.9 per 100,000, one of the lowest death rates for this disease in the United States. A review of the water supply situation in Wisconsin villages is given with details covering location and protection of wells from pollution. The elimination of cross connections is desirable.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Report of the Tri-State Treaty Commission (N. Y.—N. J.—Conn.) for Abatement of Pollution of Harbor and Coastal Waters of Metropolitan Area. New York State Legislative Document 70, 1932. The report reviews the effects of the gradual increasing pollution in the past and emphasizes the need for immediate action to arrest further depreciation of tidal waters. A definite compact or treaty between the three states is recommended, the detailed terms of which are given. It provides for the creation of "The Inter-State Sanitation District," embracing in general the lands and tidal waters of the metropolitan region from New Haven Harbor in Connecticut to Manasquan Inlet in New Jersey. It proposes that five commissioners be appointed from each state to administer the affairs of the District. The Commission would have the general power of enforcing compliance with treaty provisions by reinforcing existing State Health Departments and as a last resort by bringing action against offending communities. The proposed compact recognizes that where the tidal waters are used for such varied purposes as is the case in the Metropolitan region no uniform standards of purity are practicable. It provides for subsequent study of the waters by the Commission and their classification into two general classes, namely, Class "A" waters, which are used primarily for recreation, shellfish, and culture of fish life, and Class "B" waters which are not expected to be used for such recreational and shellfish purposes. The proposed compact provides that all sewage tributary to Class "A" waters shall be subjected to a minimum treatment and treated so as to remove all floating solids and at least 60 percent of the suspended solids, to

effect a reduction of organisms of the B. coli group so that the probable number of such organisms shall not exceed one per cubic centimeter in more than 50 percent of the samples of effluent tested by the presumptive method, and so as to maintain in the general vicinity of the point of dicharge at a depth of about 5 feet below the surface of the water a dissolved oxygen content of not less than 50 percent saturation during any week of the year.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Chronic Fluorine Intoxication. FLOYD DEEDS. Medicine, **12**: 1, 1–60, 1933. Review with bibliography of 128 titles.—*Selma Gottlieb.*

Removal of Fluorides from Drinking Water. RALPH H. MCKEE and WILLIAM S. JOHNSTON. Ind. Eng. Chem., **26**: 8, 849–51, 1934. Iron and aluminum sulfates and siliceous adsorbents gave little or no removal. Carbon from soda pulp wastes, especially after activation with acid, was effective for water containing 8 p.p.m. of fluoride, but only at pH 3.0 or less. Results were similar whether powdered carbon was added to water (0.08 percent by weight), or water filtered through granular carbon.—*Selma Gottlieb.*

Comparative Toxicity of Fluorine Compounds. MARGARET CAMMACK SMITH and RUTH M. LEVERTON. Ind. Eng. Chem., **26**: 7, 791–7, 1934. Retardation of growth rate of rats was caused by 0.0226 percent of fluorine in diet, using sodium, potassium, or ammonium fluoride, or barium or sodium fluosilicate, as source. Of fluorine from natural cryolite and from calcium fluoride 0.226 percent and 0.452 percent, respectively were required for similar effect. Minimum lethal doses of these compounds were in same relative order. One mg. of fluorine from any of above compounds per kg. of body weight per day caused first visible effect on tooth enamel of rats; but larger amounts were needed of cryolite and of calcium fluoride, than of other compounds, to cause corrosion and pitting. With exception of barium fluosilicate, all the more toxic compounds studied are relatively soluble, while cryolite and calcium fluoride are not.—*Selma Gottlieb.*

Germicidal Power of Sodium Hypochlorite. C. K. JOHNS. Ind. Eng. Chem., **26**: 7, 787–8, 1934. It is shown that greater destruction of *B. coli* at 50°C. by strongly, than by weakly, alkaline sodium hypochlorite solutions is due to combined action of temperature and pH and not to stimulation of germicidal power of hypochlorite by added alkali. Destruction of *B. coli* at 20°C. and of *Staph. aureus* at 20°C. and at 50°C. by sodium hypochlorite is markedly slowed down by added alkali.—*Selma Gottlieb.*

Mechanism of De-zincification. CHARLES W. STILLWELL and EDWARD S. TURNIPSEED. Ind. Eng. Chem., **26**: 7, 740–3, 1934. From X-ray diffraction data of corroded ε-brass, it is concluded that:—(1) in strong oxidizing agents (nitric acid), both copper and zinc are dissolved; a trace of copper is redeposited from very dilute nitric acid; (2) in acid of intermediate strength (normal sulfuric, concentrated hydrochloric), both copper and zinc are dissolved and copper is redeposited; and (3) in very weak acids (dilute hydrochloric, acetic),

only zinc is dissolved, and γ-brass, β-brass, and α-brass or copper are successively formed.—*Selma Gottlieb.*

Some Factors Involved in Soil Corrosion. E. R. SHEPARD. Ind. Eng. Chem., **26**: 7, 723–32, 1934. Greater rate of penetration in pitting than in uniform corrosion of commercial ferrous pipe is accompanied by much greater density of current discharge per unit area. Where corrosion results from general discharge of current from one portion of pipe to another, discharge density at any point is affected as much by pipe curvature as by electrical resistivity of soil. Bright iron is anodic to iron covered with mill scale when both are buried in soil; but difference decreases after some weeks of short-circuiting. Continuous mill scale film retards soil corrosion; but, if discontinous, pits may appear on exposed bright iron. Unequal distribution of oxygen on buried metal surfaces appears to be chief source of galvanic potentials, and is affected by depth, moisture content, topography, and nature of soil. In experiments over 60-day period, iron in moist silt loam corroded faster and pitted deeper than when soil was wet, or saturated. Electrical resistivity is important factor in soil corrosion, but other less definite factors may play major rôle. Secondary effects, such as solubility and resistivity of corrosion products and polarization, may have marked influence.—*Selma Gottlieb.*

Rapid Method for Determination of Small Amounts of Arsenic. C. E. LACHELE. Ind. Eng. Chem., Anal. Ed., **6**: 4,256–8, 1934. Arsine evolved as in GUTZEIT method is impinged upon impregnated mercuric bromide diaphragm, held between ground glass joints. Stains are developed in cadmium iodide solution and compared with standards. Method is applicable in presence of iron, tin, antimony, or reducible sulfur and phosphorus compounds. With 20 mm. disk, range is 0.001 to 0.04 mg. of arsenic.—*Selma Gottlieb.*

Determination of Selenium and Arsenic by Distillation. W. O. ROBINSON, H. C. DUDLEY, K. T. WILLIAMS and HORACE G. BYERS. Ind. Eng. Chem., Anal. Ed., **6**: 4, 274–6, 1934. Investigation of an animal disturbance, locally known as alkali disease, led to development of method for determination of selenium in soil, water, etc. After suitable preliminary treatment of sample, selenium is distilled off by means of bromine and hydrobromic acid and determined gravimetrically or colorimetrically in distillate, after reduction with sulfur dioxide and hydroxylamine hydrochloride. Arsenic distils over with selenium and can be determined in distillate after removal of selenium.—*Selma Gottlieb.*

Occurrence of Selenium in Pyrites. KENNETH T. WILLIAMS and HORACE G. BYERS. Ind. Eng. Chem., Anal. Ed., **6**: 4, 296–7, 1934. Samples of pyrites and pyritic materials from various places contained traces up to 250 p.p.m. of selenium. Authors believe that selenium is of much wider distribution in soils and vegetation than heretofore suspected. Results indicate that soil parent materials rich in sulfur should result, in arid or semi-arid regions, in soil having appreciable selenium content besides high sulfur content. In humid regions these elements should be almost completely leached out. Pierre shale

contained up to 103 p.p.m. of selenium; certain shallow wells in it had high sulfate content and up to 0.07 p.p.m. of selenium.—*Selma Gottlieb.*

Journal of the New England Water Works Association, Vol. 47, No. 1, March, 1933. The New High Service Water Supply of Concord, New Hampshire. PERCY R. SANDERS and FRANK A. MARSTON. 1–12. Serious shortage of water during drought of 1929–31 required emergency operation of Pembroke station to augment Penacook Lake supply. Pembroke Well Field, covering 28 acres adjacent to Soucook River, yields water relatively free from iron. One hundred fifty 2½-inch wells, of depths varying from 30 to 50 feet, were connected into suction headers of 8-, 10-, and 12-inch cement-lined sand-cast pipe, with lead-filled bell and spigot joints. Suction lines were tested for leaks with 80 pounds air pressure. Pumping station contains 3 electrically driven centrifugal pumps, each of 1150 g.p.m. capacity. Discharge from station, in 12-inch cast-iron pipe 15,636 feet long, connects with high service system of city. Cost of new installation was $162,578. **Experience with Ammonia-Chlorine Treatment of the East Providence, Rhode Island, Water Supply.** JAMES V. TURNER and CHARLES L. POOL. 13–21. Control of taste and odor, higher residual chlorine with elimination of after growths, and prevention of incrustation of pipes in clear well followed chloramine treatment of water supply started in March, 1931. Filters are cleaner, although runs have not been prolonged, water is uniform, and customer complaints have been reduced. The twenty-minute period between point of chlorine application and the first service was sufficient to insure a water free from *B. coli* in 10-cc. portions. **Replacement of Brook Crossing with Bridge Crossing on 42-inch Pipe Line.** HAROLD W. GRISWOLD. 22–26. Installation of new roadway and extension of bridge to full width of highway endangered 42-inch main laid in river bed and supplying north section of Hartford, Conn. Re-location necessitated placing of headers in 42-inch water line at either end of bridge and connecting them with several parallel lines sufficiently small to be installed between arch and sidwalk. **The Design of Pipe Lines.** KARL R. KENNISON. 27–39. Following are points discussed. (1) Determination of invert grades to keep air pockets at a minimum. (2) Prevention of air-binding, when starting flow. (3) Automatic creation and maintenance of vacuum to allow safe economical location of pipe line above hydraulic gradient. **Manganese in Impounded Water Supplies.** ROBERT SPURR WESTON and ATTMORE E. GRIFFIN. 40–51. Manganese in impounded water is due mainly to decomposition of organic vegetable matter in bottom of reservoir, which causes acid condition and solution of manganese. Hydrogen sulfide is usually present. During fall turnover, manganese is distributed throughout entire body of water. So long as pH is low, manganese will oxidize but slowly; but contact with highly alkaline concrete surfaces, or with manganese bacteria lining inside of pipes, will result in precipitation with subsequent "black water" and complaints from consumers. *Ortho*-Tolidine test, being affected by manganese, should be supplemented by other tests for residual chlorine. In practice, manganese nuisance can be minimized by drawing off the bottom water during periods of stagnation. **Reconstruction of the Lebanon, N. H., Water Works.** RICHARD S. HOLMGREN. 52–60. Supply is drawn from Mascoma River, within the

town limits, treated by rapid sand filters, and pumped to distribution reservoir by hydraulic-turbine-driven pump, utilizing water from river for power. In October, 1928, water undermining the wheel foundation necessitated rebuilding the plant. Equipment was modernized. **The High Speed Diesel Engine as a Prime Mover for Pumping Stations.** ELLIOTT EARL. 61–73. Origin of Diesel engine is traced. Despite somewhat high first cost, Diesel high-speed engine is, theoretically and practically, most efficient type of prime mover made. But, more important for water works, pumps driven by Diesel engines are a more reliable source of water supply for a lower net cost and are invaluable as standby equipment for electric stations. **Relation of Geology to the Ground Water Supplies of New England.** IRVING B. CROSBY. 74–95. Three groups of rocks predominate in New England: (1) porous rocks, congomerates and sandstones which ordinarily have a large water capacity; (2) limestones, which are soluble, so that eventually caves and true underground rivers may appear; and (3) dense crystalline rocks, as granite, which predominate and usually contain water in the cracks which intersect them. Glacial deposits are important as a source of groundwater. Adequate geological survey prior to placing a well will reduce failures and eliminate danger of obtaining polluted supplies.—*T. F. Donahue.*

City Cuts Pumping Bill 64 Percent. Anon. The American City, **49**: 5, 50, May, 1934. Las Animas, Colo., water supply is secured from two wells, one pumped by electric, and the other by Diesel power. Comparison of operating costs after thirty-day test revealed cost of electric power per 1000 gallons to be 2.07 cents, and that of Diesel power, 0.75 cent, a saving of 64 percent.—*Arthur P. Miller.*

The New Steel Intake Line at Traverse City, Michigan. W. S. WILLIAMS. The American City, **49**: 5, 56–57, May, 1934. Hammerwelded pipe, asphalt-coated, was chosen, on account of its resistance to corrosion. New pipe was transported to installation point by scow and sections connected under water by diver. Simple bolted socket joint with retaining shoulders was used. New line leads to new intake crib 1700 feet from shore in 45 feet of water, crib being 16 feet square, of timbered construction, with a centered open pocket 8 feet square, boarded over. Except for center square, other crib pockets were filled with 3-inch gravel.—*Arthur P. Miller.*

The Water Supplies of the Federated Malay States. Notes on Some of the Water Supplies Derived from Jungle Streams and Rivers. R. W. BLAIR. Bull. Inst. M. Res., Federated Malay States, 1933, **2**: 166 pp. From Bulletin of Hygiene, **8**: 12, 817, December, 1933. Results of systematic chemical tests of 34 water supplies derived principally from jungle streams are given in this bulletin. These cover monthly tests during 1932 and averages for previous four years. Details of rainfall and climate and short descriptions of supplies and purification methods are also included.—*Arthur P. Miller.*

Notes on the Chloramine Treatment of Water. S. ELLIOTT. J. Roy. Army M. Corps, 1933, **61**: 161–79. From Bull. of Hygiene, **8**: 12, 817–18, December,

1933. In chloramine treatment of water ammonia gas may be used, but must be kept from contact with chlorine gas until they are mixed in dilute solution, on account of risk of explosion due to formation of nitrogen trichloride. Chloride, or sulphate, of ammonia may conveniently replace gas. Ammonia and chlorine may be mixed and added to water, or else ammonia added first and chlorine, after mixing. First may be styled pre-formed, and second, bulk-formed, chloramine process. In using pre-formed chloramine, concentrations of solutions mixed together before addition to water should not exceed 100 p.p.m., nor should mixture be prepared for long in advance.—*Arthur P. Miller.*

The Treatment of Water by Certain Forms of Silver. J. GIBBARD. Amer. J. Pub. Health, 1933, **23**: 910–16. From Bull. of Hygiene, **8**: 12, 818, December, 1933. Purification by oligodynamic action does not possess all the virtues heretofore claimed for it. Period of exposure to silvered materials necessary for disinfection depends upon number of organisms present and also upon amount of organic matter present. Temperature affects rate of action, it being slowed up with lower temperatures. Conclusion is that oligodynamic action cannot yet be recommended for practical use, because so many factors influence its efficacy.—*Arthur P. Miller.*

Lead Poisoning in the North-East of Scotland. L. S. P. DAVIDSON and others. Lancet, **1933**, August 12, 374–7. From Bull. of Hygiene, **8**: 12, 818, December, 1933. As result of three lead-poisoning cases admitted to an Aberdeen, Scotland, hospital, 160 water supplies of different areas were examined and excessive lead found in 108. Permissible limit of lead was taken to be less than 0.05 parts per 100,000. Other evidence collected showed that lead in water supplies was still a matter of importance in this area.—*Arthur P. Miller.*

Boston's Lead Poison Problem. New England J. of Med., 1933, **209**: 559–60. From Bull. of Hyg., **8**: 12, 818, December, 1933. Many house connections in Boston are made of lead. When condition of hospital patient led to suspicion of lead poisoning, examination was made of water used at patient's home and revealed lead content above danger line. The amount of lead found in the water from a number of houses showed lead contents ranging from 0.60 to 1.14 p.p.m. Chlorination has added to danger from these leaden pipes.—*Arthur P. Miller.*

Zinc in Drinking Water. A. G. NOLTE and W. A. KRAMER. The American City, **49**: 4, 63–64, April, 1934. Older literature reveals conflicting opinions and experiences regarding harmful effects of zinc in drinking water; recent investigations are more in agreement. DRINKER and FAIRHALL suggest that if limit on zinc is desirable, 30 p.p.m. would be appropriate. The authors conducted some experiments with strips of galvanized iron in tap water, in water with pH adjusted, with lime to 10.5, and also with CO_2, and tests were made of residual zinc in tap samples. Largest concentration of zinc found in water from any much-used tap was 5 p.p.m., which figure was not exceeded until galvanized pipe had stood in tap water over 24 hours. Zinc was found to

dissolve readily in strongly acid water and in caustic alkaline solutions; but in water only weakly acid or alkaline, such as drinking water, solution of zinc proceeded slowly. Excess zinc in water turns it opalescent and causes a greasy film on boiling, and hence is esthetically objectionable. Authors conclude that zinc, in amounts as found in drinking water, has no harmful physiological effects, although its appearance is uninviting.—*Arthur P. Miller.*

When and How to Wash a Filter. A. V. GRAF. Water Works Eng., 1932, **85**: 1516. From Bull. of Hygiene, **8**: 9, 618, September, 1933. Loss of head at which filter should be washed is that at which smallest percentage of wash water is necessary, showing that filter is not caked and that suspended matter has not penetrated into deeper sand. Sand expansion should be as great as possible, but no sand should be washed into overflows. Although not possible with all filters, 50 percent rise will generally prevent excessive sand settlement.—*Arthur P. Miller.*

The Connection between Water Supply, Soil Pollution, and Intestinal Disease. C. P. MOM. Verlag Abrecht & Co., Batavia-C. 26 pp. Gas- u. Wasserfach, 1932, **75**: 364. From Bull. of Hygiene, **8**: 9, 618, September, 1933. Proportion of typhoid to colon bacilli in water is generally between 1:1,000 and 1:100,000. Intestinal bacteria multiply rapidly when nutriment available, so that complete safety in drinking water requires absence of *B. coli*. Typhoid bacteria have been found alive in soil 95 days after burial of victim of that disease. *B. coli* placed in soil were found after 37 days in water of well 50 meters away. These facts and others are leading to substitution of sewerage systems and central water supplies for septic tanks and ground filtration plants now customary in Dutch East Indies.—*Arthur P. Miller.*

Sanitation and Water Purification. A. PARKER. Reps. Progress of App. Chem., 1932, **17**: 626. From Bull. of Hygiene, **8**: 9, 619, September, 1933.—*Arthur P. Miller.*

Twenty-Seventh Annual Report on the Results of the Chemical and Bacteriological Examination of the London Waters for the Twelve Months Ended 31st December, 1932. Metropolitan Water Board, London. From Bull. of Hygiene, **8**: 10, 685–86, October, 1933. Among other interesting items, this report contains epilogue to Epping paratyphoid outbreak of February, 1931. Examination of samples of Epping sewage since outbreak, and through 1932, and comparison of results with those obtained from sewages from other areas make it clear that persistence of *B. paratyphosum B* in large numbers in Epping sewage (20 samples varied from 40 to 7,600 per cc.) is due to presence in that area of carriers remaining from 1931 epidemic.—*Arthur P. Miller.*

An Investigation into the Bacterial Pollution of Swimming Pools. Section I. The Pathogenic Organisms that can be Isolated from Swimming Pools, with Special Reference to Sea-Water Baths and their Importance in the Spread of Disease. B. L. DAVIS. J. Roy. Army M. Corps, 1933, **60**: 81–94; 181–90; 335–7. From Bull. of Hygiene, **8**: 10, 687, October, 1933. Daily examinations

made at Aberdeen on samples of natural sea water, sea-pool water after use, and filtered chlorinated water from a fresh-water pool for 3½ to 4 months, showed average bacterial counts of 27.3, 408.6, and 5.8 per cc., respectively. Pathogenic bacteria isolated from the sea-pool included hemolytic and non-hemolytic streptococci, staphylococci, Gram-negative cocci, and a few diphtheroids, chromogenic bacteria, and *C. welchii*. Commonest streptococci found were not of intestinal origin, as stated by MALLMANN. Writer believes that certain factors fatal to streptococci in unused water do not affect *B. coli*. Individual infection from swimming-pool is possible; but there is no evidence for spread of epidemics.—*Arthur P. Miller.*

New Data Concerning the Action of Silvered Sand Filters for the Sterilization of Water. W. A. UGLOW and T. W. UGLOWA-OWTSCHINNIKOWA. Milit.-Med. Ztschr. Moscow, 1933, **4**: 95–101. From Bull. of Hygiene, **8**: 11, 747–48, November, 1933. Prolonged experience has shown that filters are easily clogged by colloidal particles suspended in water and their output greatly diminished, although their sterilizing properties remain unaltered. Important factors are size of sand grains and duration of contact between sand and water. The more firmly silver adheres to sand, the less pronounced is bactericidal efficiency; but, at the same time, the more even and regular.—*Arthur P. Miller.*

Experiments with Triseptol. SARDJITO. Meded. Dienst. d. Volksgezondheid in Nederl.-Indie, 1932, **21**: 280–85. From Bull. of Hygiene, **8**: 11, 749–50, November, 1933. This chlorine preparation similar to caporit contains up to 80 percent available chlorine. When 250 gm. were added to 4 cubic meters of sewage, containing innumerable organisms, their number was reduced after two hours to less than 25 per cc. Other tests on specific cultures lead author to believe that triseptol is not inferior to caporit as a disinfectant, and is much cheaper.—*Arthur P. Miller.*

An Ornamental Enclosure for a Steel Water Tank. Anon. The American City, **49**: 2, 63–64, February, 1934. Steel water tank 110 feet in diameter and 60 feet high was considered undesirable feature on landscape in Curtis Bay District of Baltimore. Circular reinforced brick wall was built, completely inclosing it, but leaving 2½ foot space between wall and shell of tank. Twenty varying color tones are represented in face-brick exterior, shading being graded from dark at bottom to light at top. There are 24 depressed panels in it and resultant ensemble is attractive and pleasing.—*Arthur P. Miller.*

Preventing Tuberculation in Water Lines. LEONARD P. WOOD. The American City, **49**: 2, 65–66, February, 1934. Improved cement pipe linings have increased the carrying capacity for tuberculating waters by 20 to 100 percent. Purpose of water main is to carry water, and as carrying capacity diminishes, value of main as investment shrinks. Consequently, any device which will reduce tuberculation is worthy of attention of water engineers. Article gives history of cement linings, consideration of specifications for same, and discusses briefly cement-lining solubility.—*Arthur P. Miller.*

Per Capita Consumption: Is It a Reliable Measuring Stick? H. P. BOHMANN. The American City, 49: 3, 61, March, 1933. Metering in Milwaukee, Wisconsin, began in 1887. Prior to that time, water consumption had been rising from year to year. As more meters were installed, per capita consumption went down until 1901, when it was 80 gallons. Since then, it has increased, until, during last year, it attained 122 gallons. In an industrial city like Milwaukee, per capita consumption has but little significance, because of large amount of water used by industries. Complete meterage alone makes it possible for water utility to have reliable information regarding use of water. When daily per capita use was 80 gallons, unaccounted for water amounted to 25 percent; but last year, when consumption was 122 gallons, unaccounted for water was only 9 percent.—*Arthur P. Miller.*

Dome Roof on Elevated Steel Water Tank. ARTHUR L. SCHMIDT. The American City, 49: 3, 65, March, 1933. Appearance dictated design of tank at Youngstown, Ohio, with ellipsoidal bottom and dome roof. It has capacity of ½ million gallons, is 128 feet above ground, and 51 feet in diameter. Other figures on Youngstown water distribution system are given.—*Arthur P. Miller.*

The Recent Trend to Municipal and Public Ownership. R. E. MCDONNELL. The American City, 49: 3, 62–63, March, 1933. In 1800, only one municipality in United States owned its water works. Now, 72.8 percent of entire number, or 7853 water works, are municipally owned. These plants serve 96.1 percent of population of the 94 cities over 100,000. All of largest cities own and operate their water works. Average American family used 5,000 gallons of water a month, which costs in municipal plants $1.41, as compared to $2.24 in private plants.—*Arthur P. Miller.*

Estudio geologico del valle de Tecocomulco, Municipio de Cuantepec, E. de Hidalgo. (Geologic Study of the Valley of Tecocomulco, County of Cuantepec, State of Hidalgo). VIVAR, GONZALO. Irrigacion en Mexico, 6: 6, 513–531, June, 1933. Describes the communications, physiography, hydrography, and geology. Basalts and rhyolites occupy greater part of valley. Artesian water is not available. Ground water occurs in the basalt and in the overlying alluvium; but these 2 bodies of water are not directly connected.—*S. F. Turner.*

Experiencias de aforo de aguas subterraneas por el procediminento electrico, en el Rio Pilon, N. L. (Experiences Measuring Underground Waters by the Electrical Method, in the Rio Pilon, N. L.). DE LA VEGA, JOSÉ S. Irrigacion en Mexico, 6: 6, 487–513, June, 1933. Following SLICHTER'S method, 4 wells were driven at carefully selected sites and salt was introduced into the upstream well. Time of arrival of salt solution in each of 3 downstream wells was recorded electrically and direction and velocity of flow determined thereby. Volocities as high as 0.0016967 meter (.00557 foot) per second were obtained.—*S. F. Turner.*

Beobachtungen am Rande der Wuste: Die Oasen. (Observations on the Borders of the Desert: Oases). W. BEHRMANN. Geograph. Zeitschr., 38:

7, 405–412, 1932. Abstract in Geol. Zentr., 49: 3, 148–149, April, 1933. Classifies irrigated areas according to source of water, i.e., well water, spring water, artesian water, river water, etc., and points out that drainage is nearly as important as irrigation, because rapid evaporation concentrates the salts in the water and provision must be made for flushing them away.—*A. N. Sayre.*

Microflora of Oil Waters and Oil-Bearing Formations and Biochemical Processes Caused by It. T. L. GINSBURG-KARAGITSCHEVA. Am. Assoc. Petroleum Geologists, Bull., 17: 1, 52–65, January, 1933. Examination of more than 100 samples, collected from oil wells and sulphurous springs in various oil regions of Russia, showed presence of certain micro-organisms characteristic of waters charged with hydrosulphurous fermentation. This microflora reduces sulfates, with formation of H_2S and FeS, and may play a large part in formation of natural gas and petroleum and account for low sulfate content of oil field waters.—*S. F. Turner.*

East Texas Oil Field. H. E. MINOR and MARCUS A. HANNA. Am. Assoc. Petroleum Geologists, Bull., 17: 7, 757–792, July, 1933. Gives brief history of field, its geology and production, with good description of water encroachment (pp. 785–791) and permeability (p. 783). Attempts to estimate, on basis of actual experience in Powell Field, amount of ground water flowing into the area from surrounding area.—*S. F. Turner.*

The (English) Law in Relation to Subterranean Water Supplies. EDGAR MORTON. Water and Water Eng., 35: 414, 69–74, February 20, 1933. History, description, and results of litigation in Derbyshire, England, concerning priority rights of underground water. English law states that riparian owners have water rights on known and defined subterranean channels, but do not possess rights where ground water simply percolates through the ground, having no certain course and no defined limits. In this case, defendant proposed to sink shafts upgradient from a spring and plaintiff moved for injunction to restrain defendant on ground that proposed works would deplete the spring and hence, plaintiff's water supply. Excavation work was carried on directly above the spring, and ground water was found to be moving toward the spring through numerous cracks and fissures in sandstone. Court ruled that fissures did not constitute definite channels and that, no matter how serious the result to plaintiff, there was no legal ground to prevent defendant from collecting percolating ground water above the spring.—*L. K. Wenzel.*

Porosity and Water Absorption of Forest Soil. J. T. AUTEN. J. Agr. Res., 46: 11, 997–1014, December, 1933. Forest soil is much more porous than field soil and is most porous in top six inches. Differences are due to soil structure. Impact of rain produces surface crust on bare soil which hinders water absorption. Absorption is most rapid at 1-inch depth in forest soil. When overgrazed, forest soil becomes less porous.—*R. M. Leggette.*

Ammonia in Water Treatment. L. H. ENSLOW. Water Works and Sewerage, 80: 10, 379, October, 1933. Has become an established practice, in order:

(1) to prevent taste formation by reaction of chlorine with foreign substances; (2) to reduce, somewhat, chlorine requirements of potable and swimming pool water, owing to its stabilizing effect on chlorine residual, period of activity of which is considerably prolonged; (3) to prevent tastes caused by residual chlorine, in especial, those in swimming pools; (4) by reason of prolonged disinfecting activity, to prevent algae growths in open reservoirs and after-growths in reservoirs and distribution systems, thus effectively controlling "dead-end" troubles; (5) to control with greater effect and economy "slime" growths in pipe lines and vats of paper and pulp manufacturing plants by its stabilizing action on chlorine. Short ammonia treatment discussion.—*R. E. Noble.*

Water Purification. E. S. HOPKINS. Municipal Sanitation, **5**: 3, 85, March, 1934. Present day methods chiefly include: (1) storage, or natural sedimentation, in large reservoirs; (2) chemical turbidity coagulation; (3) coagulated floc sedimentation, minimizing filter bed load; (4) sand filtration, removing turbidity; (5) disinfection (chemical or physical) to eliminate disease germs; (6) aëration, or physical adsorption, removing tastes and odors; (7) hardness reduction, by chemical precipitation or by base exchange; and (8) alkali treatment to eliminate corrosion. Fundamental task of water purification is to provide a safe supply, free of disease germs, and free of dirt, of color, and of undesirable taste or odor. Corrective treatment to minimize household and industrial troubles should also be undertaken.—*R. E. Noble.*

Handling Sugar Beet Wastes in a Municipal Water Plant. W. D. LOREAUX. Water Works and Sewerage, **81**: 2, 61, February, 1934. Dundee, Mich., Filtration Plant supplements lime-soda softening process with other treatments for River Raisin supply. Beet-sugar factory wastes present serious problem. Writer concludes that supplementary P. A. C. treatment, including pre-ammoniation and pre-chlorination, (1) is economical; (2) is flexible; (3) keeps settling basin sludge sweet; (4) is applicable all year round, if needed; and (5) removes, practically completely, objectionable tastes and odors due to beet-sugar factory wastes.—*R. E. Noble.*

Flow Diagrams for the Chemical Treatment and Filtration of Water. JOHN R. BAYLIS. Water Works and Sewerage, **81**: 2, 65, February, 1934. This article gives typical flow diagrams for: (1) aluminum sulfate treatment; (2) lime and ferrous sulfate treatment; (3) softening. Shows different points of application proposed for various chemicals, specifying points where, in majority of plants, they are most advantageously added. Other treatments discussed.—*R. E. Noble.*

Results from the Use of Activated Alum at Batavia, N. Y. H. M. COOK. Water Works and Sewerage, **81**: 2, 47, February, 1934. As compared with alum, activated alum (Blackalum) seems more flexible, giving quicker-forming, larger, and more easily controlled floc. Sludge in settling basins, or in filter sand, does not seem to decompose, as even during prechlorination it does

with alum. Activated alum has been found to improve taste and odor, with 20 percent reduction in alum consumption. Less wash water is needed and filter beds keep in better condition.—*R. E. Noble.*

The New Filtration Plant of Easton, Pa. R. W. HAYWOOD, JR. Water Works and Sewerage, **80**: 10, 349–353. October, 1933. Plant with some unusual features described.—*R. E. Noble.*

Development of Sanitation in a Russian Industrial City. ISADOR W. MENDELSOHN. Municipal Sanitation, **5**: 3, 84, March, 1934. Kharkov water supply is now obtained from series of shallow and deep wells in outskirts, connected to section pumping station housing pumps and air compressors. Twenty-five percent of water is filtered to remove iron (0.5 to 0.7 p.p.m.) and mixed with remainder in covered earth reservoirs, from which distribution system is fed by pumping. Water raised by air-lift is not filtered. From aërators, consisting of layers of perforated wooden trays, water runs over wooden collecting system to filters which contain 10 inches of sand over 16 inches of gravel. In summer 1931, 65 wells with six pumping stations supplied 13.2 m.g.d. During 1931 were added 4 new pumping stations, 32 wells, covered earth reservoirs, and iron filtration stations; expenditure 2.5 millions. In 1932 were added 43 new wells and other units. In 1933, an American design rapid sand filtration plant was being constructed to treat river water: intake and plant are located 22 miles from city. Samples from various pump stations are analyzed semi-weekly by Water, Canalization, and Health Laboratories, according to standard chemical and bacteriological methods. Of sewage, 10.56 m.g.d. is pumped by 3 stations 2 miles to treatment plant. In 1931, only 50 percent of population and 20 percent of houses had access to sewers. Number has materially increased since addition of pumping station in 1932: 3 others are planned for near future. Sludge irrigation field (12 acres in 1931) has been increased yearly; increase to 12,350 acres is planned. Trickling filter of 924,000 gallons daily capacity, completed in 1932, is of Dunbar type, with coal slag medium. Rostov-on-Don water supply is from Don River, intake and pumping station being 7.5 miles from rapid sand filtration plant, which in 1931 delivered 8 m.g.d. and in 1932, 3,458 m.g., an increase of 126.7 percent. In this period, coinciding with First Five Year Plan, number of houses connected to water system increased 198.2 percent. Pipe lines increased 45 percent. Plant includes (1) mixing tanks using lime and alum during three spring months; at other times, alum alone; (2) ELLMS hydraulic flume; (3) four round concrete clarifiers, with upward flow; (4) two collecting tanks where chlorine in solution is applied from (5) four American chlorinators; (6) eight filters; (7) clear water well, capacity 1.7 m.g.; (8) 118-foot, 270,000-gallon concrete and iron tower. Pump-house contains German centrifugal pumps, electrically driven. Filter drainage system design is based on experience at Sacramento, California, filtration plant. The plant is clean. A complete laboratory is headed by university graduates, analyses being made according to standard methods. City outgrew filtration plant and other water works improvements completed in 1929–30; in 1931, work was begun on new plant adjacent to existing one. Present plant capacity is 18.5 m.g.d.,

when using BAYLIS method of chemical treatment, four-hour settling period, with clarifiers. Filter sand (0.45 mm.) is 30″ deep. Chlorine (1 p.p.m.) is applied prior to filtration. During new construction, armed guards exclude strangers and photographs are prohibited.—*R. E. Noble.*

Water Works Improvements at Williston, North Dakota. C. KELSEY MATHEWS. Water Works and Sewerage, **80**: 11, 395, November, 1933. Plant was constructed for three phases of treatment: (1) clarification and (2) softening, of Missouri River water, and (3) removal of sodium carbonate from well water. First phase may be accomplished either alone, or simultaneously with second. Other unusual features are: double pumping of filtered water; pressure cover over the new clear well; housing of new filters, mixing basins, and clarifiers under one roof; and construction of concrete manholes over all yard valves.—*R. E. Noble.*

Roadside Drinking Water and Public Comfort Stations. J. R. BAYLIS. Water Works and Sewerage, **80**: 2, 451. December, 1933. Article stresses importance of public comfort stations, and menace of unsafe drinking water, and includes discussion on common drinking cup, for auto or bus travelers. Author believes state should provide public comfort stations and camp sites with safe water supply, at reasonably frequent intervals along roadside.—*R. E. Noble.*

Progress in American Water Supply and Purification Practices During 1933. H. E. JORDAN. Water Works and Sewerage, **81**: 1, 1, January, 1934. Discusses new plants, iron salts as coagulants, progress with taste and odor control measures, economical handling of chlorine, and laboratory improvements necessary.—*R. E. Noble.*

The Water Supply of London. A. HOUSTON. Water and Water Engineering, **35**: 418, 271–273, May 20, 1933. Abstract of lectures to Sanitary Inspectors' Association, giving notable events in history of Metropolitan Water Board and dealing with purification, storage, filtration, and chlorination. Statistical data show that storage capacity for unfiltered water totals 19,657 million gallongs, and for filtered water, 340.1 million gallons. Average daily supply is about 281 million gallons or about 39 gallons per head per day. Chart showing decrease in typhoid fever in London since 1900 is given (from 4,300 in 1900 to 200 in 1932).—*W. G. Carey.*

Floods in Relation to Reservoir Practice. Water and Water Engineering, **35**: 424, 593–595, October 20, 1933. Interim report of Committee of Institution of Civil Engineers states that study of reservoir failure indicates that insufficient provision is made for flood water disposal. Report deals almost exclusively with overflow weirs for earth embankments and has been compiled on actual records of floods in British Isles. Graphs show normal maximum flood intensities from various catchment areas, total flow, and lengths of weir necessary to discharge at different heads. When reservoir area exceeds 2 per cent of catchment area, lag effect reduces rate of outflow and shorter weirs

are possible. Methods for calculating lag effect and for estimating weir lengths necessary for reservoirs in series are given.—*W. G. Carey.*

Newcastle (England) and District Water Supply. R. WALTON. Water and Water Engineering, **35**: 423, 559–565, September 20, 1933. General description of gathering grounds, reservoirs, pipe lines and filters; with notes on water purification. Storage capacity is 5371 million gallons and daily consumption, 22 million gallons, or 34.28 gallons per head. Catcleugh reservoir, with capacity of 2305 million gallons, is formed by earth dam across valley in Cheviot Hills, 42 miles from Newcastle. Pipe line to city is 30-inch cast iron, delivery through which dropped from 11.25 to 7 million gallons per day owing to nodulous growths. As scraping machines were found cumbersome and inapplicable, manual scraping is employed, method being described. Water from this and other gathering grounds and reservoirs is filtered in 70 pressure filters, with output of 11 million gallons per day, and then chlorinated. Unfiltered water for industry is supplied through 24-inch pipe, laid in 1848, which was then largest cast iron pipe in world.—*W. G. Carey.*

The Largest Rapid Filter Plant in Europe. Anon. Water and Water Engineering, **35**: 420, 408, June 20, 1933. Water purification plant for Warsaw was opened in March; capacity of Jewell filters is 60 million gallons per day and they are fitted with most efficient equipment obtainable.—*W. G. Carey.*

The Economics of Service Reservoir Construction. S. MCCONNEL. Water and Water Engineering, **35**: 413, 16–21, January 20, 1933. Article deals with general principles of service reservoir construction in reinforced concrete, including economic proportions, roofing of galvanized iron, or concrete, boundary walls, and economy of earth backing. There are 10 diagrams.—*W. G. Carey.*

The Design of Wedge Gate Sluice Valves. G. H. PEARSON. Water and Water Engineering, **35**: 422, 500–502, August 21, 1933, and 423, 553–558, September 20, 1933. Data resulting from many years experience in design and operation of valves are collected to assist designer to evolve satisfactory type. Body chest thickness, spindles, torque to effect closure, handwell, cover flanges and yoke, stuffing boxes, seat and gate facings and wedge nuts are dealt with mathematically.—*W. G. Carey.*

The Application of Nitrogen-Hardened Steel and Cast Iron in Hydraulic Engineering. J. E. HURST. Water and Water Engineering, **35**: 423, 541–544, September 20, 1933. Chromium-aluminum steels and cast irons exposed to anhydrous ammonia at 500°C for 40–90 hours absorb nitrogen, acquiring superhardened surfaces of over 1000 Brinell. Nitrogen-hardened materials are used for pump rotors, plungers, shafts, and sleeves, valve seats, dredger pins, and links.—*W. G. Carey.*

Measuring pH. Anon. Water and Water Engineering, **35**: 418, 280–282, May 20, 1933. Descriptions of Cambridge electrometer valve pattern meter

which is calibrated in 0.02 pH for range of 14 pH units and can be used with any electrode. Morton glass electrode is described and illustrated; electrical connections with inner surface of glass electrode are made by quinhydrone half cell within glass electrode; and glass electrode may be interchanged with quinhydrone, hydrogen, or antimony electrodes. Notes on calculation of pH value from observed E. M. F. are given.—*W. G. Carey.*

The Electrical Study of Dam Foundations. M. LUGEON and C. SCHLUMBERGER. Water and Water Engineering, **35**: 424, 609–613, October 20, 1933. Definite relationship exists between specific electrical resistance of granite and its degree of weathering as well as its permeability to water; for specific conductivity of rock is approximately proportional to amount of water and salts absorbed therein, and weathered and pervious granite must contain larger percentage of water than compact granite. Based on about 500 measurements, it was found that granite on which Sarrans (France) dam is built gave electrical resistivities larger than 5,000 ohms per square meter, but below that figure in zones where it is weathered and pervious. Drill holes showed definite relation between resistivities and coefficients of absorption, as is shown on curves reproduced. Electrical prospecting is valuable in studies of dam foundations, tunnel sites, spillways, etc.—*W. G. Carey.*

Wilson and Blair's Medium. B. A. A. Water and Water Engineering, **35**: 424, 595–598, October 20, 1933. Résumé of work since 1923 by WILSON, BLAIR, and others on sulphite-glucose-iron agar culture medium, with later addition of bismuth salt, whereby *B. coli* growth is inhibited and typhoid-paratyphoid organisms develop rapidly as well defined black colonies, owing to their reduction of sulphite to sulphide. With this medium *B. typhosus* has been isolated from sewage, shellfish, feces, and water by WILSON and BLAIR, from gull excretions by ADAMS, and from raw Thames water by HOUSTON. List of references is given.—*W. G. Carey.*

Water Supplies of the Federated Malay States. R. W. BLAIR. Water and Water Engineering, **35**: 424, 621–622, October 20, 1933. There are 34 supplies, comprising pumping and gravitation systems, standard of purity being that of Metropolitan Water Board, England. Kuala Lumpur water is from jungle streams, partly impounded in Ampang reservoir, holding 40 million gallons, other supplies coming direct from streams. Slow sand filters are employed and water is now chlorinated. Bagan Serai supply is drawn from irrigation canal supplying rice fields and is treated with aluminum sulphate in sedimentation tank before filtration by mechanical filters. Rawang has catchment area of 53 acres, supply is untreated.—*W. G. Carey.*

Algal Growths and Water Supply. J. W. HUSBAND. Australian Munic. Journal, pp. 385–7, January 31, 1934. From paper before Institution Civil Engrs., London, December 1, 1933. Study of unpalatable conditions at Bedford (Eng.) waterworks. Fissured Oolite beds permitted infiltration from river. Concrete slopes of storage reservoirs were coated with 2-inch layer of decomposing algae for 4 feet downward from high water line. Bottom

was covered with 11-inch deposit of foul smelling slime. Total amount of foul organic matter proved to be 200 tons. Reservoir had not been cleaned for 4 years, in belief that plant and fish life would suffice to purify water. Fresh growth of spirogyra was seen, except where current shortcircuited through basin. Water had grassy taste, but was free from odor. Drawing down of reservoir developed large bright red patches about 70 square feet in total area, rest being slimy. Patches were dense swarms of minute water fleas. Sand filters were covered with 1½-inch of dark brown coating of algal débris, diatoms, and fine mineral silt. Treatment with 5 pounds per m.g. (Imp) of potassium permanganate removed all traces of growth after 12 days. Dosage of 25 pounds completely disintegrated patches of spirogryra and associated algae in 7 days. Plant practice showed that doses of from 2 to 25 pounds per m.g. (Imp) of solid potassium permanganate prevented any appreciable algal development in reservoirs under any sunlight conditions. Suitable pre-filtration treatment was devised. Attention is called to small size of *Synedra*, which can easily pass into filter if no gelatinous film on surface.—*E. B. Besselievre.*

Industrial Water Problems and Their Correction. SHEPPARD T. POWELL. Paper Trade Jour. No. 15, 24–27, April 12, 1934. Read at New Eng. Sec. Tech. Assoc. Pulp & Paper Industries, Holyoke, Mass., March 23, 1934. Controlling factors in adequate water conditioning are indicated. Uses of water in industrial plants include steam-raising, fire protection, and sanitary purposes. For paper making, coagulation, decolorization, and filtration are necessary. Suitable mixing devices conserve chemicals and promote flocculation. Iron and alumina coagulants are compared. Iron treatment, properly controlled, is applicable in white paper manufacture. Chlorination aids coagulation by hastening floc formation. Ferric sulfate is preferred to ferrous. Settling basin design is important and mechanically-cleaned basins are economical, especially on heavily silted waters. Filtration unit efficiency depends on design. Open-type, gravity filters are recommended due to ease of inspection and control. Engineering advice is expedient. Proper treatment of boiler feed water, to maintain boiler efficiency, to prevent scale, and to inhibit corrosion and embrittlement, requires careful study of all conditions. Initial cost is false criterion of economy. External removal of incrustants is favored. Failure of boiler steel is discussed. Sulfates inhibit embrittlement. Corrosion problems assume major importance in paper plants. Types of corrosion and their correction. When residual oxygen in deaërated water is kept below 0.03 cc. per litre, corrosion will be limited. Water for fire protection should be from separate source and cross connections prohibited. Drinking fountains need attention. Bacteriological studies show that vertical jet fountains retain disease germs for long periods and records show transmission by them of disease. Cases are cited. See Woman's Bureau, U. S. Dept. Labor, 1931 report for cases and for specifications of proper fountains.—*E. B. Besselievre.*